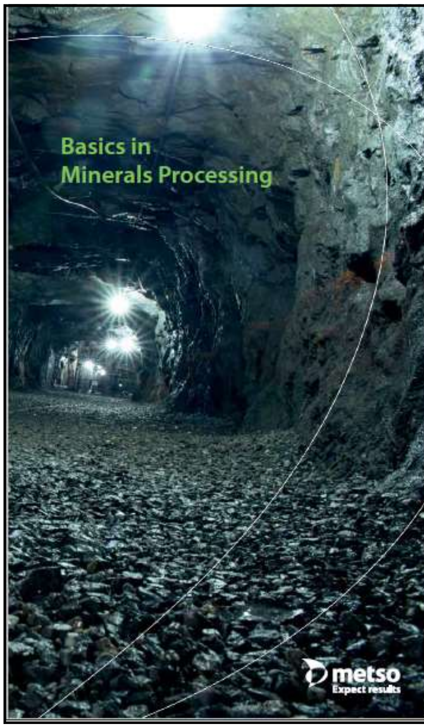
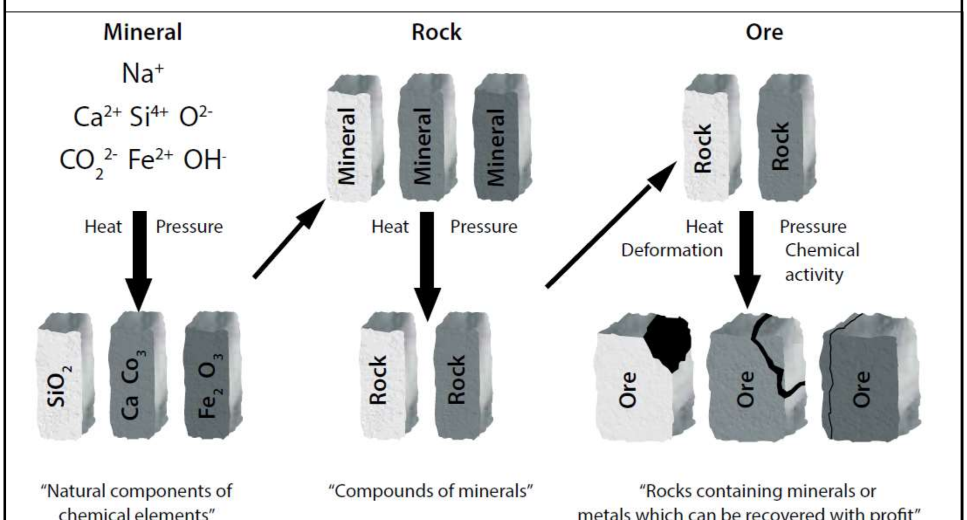


تصاویر، نمودارها و جداول مفید کتاب

Basics in Mineral Processing

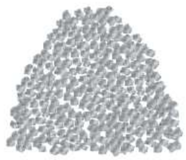
Basic definitions

- It is important to know the definitions of mineral, rock and ore as they represent different product values and partly different process systems.

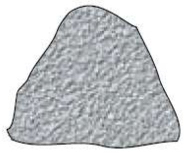


Artificial minerals

- "Man made" minerals are not minerals by definitions. But from processing point of view they are similar to virgin minerals and are treated accordingly (mainly in recycling processes).



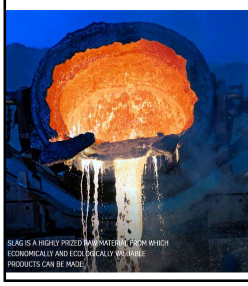
Slag



Concrete

Mill scale

Glass & Ceramics



Minerals by value

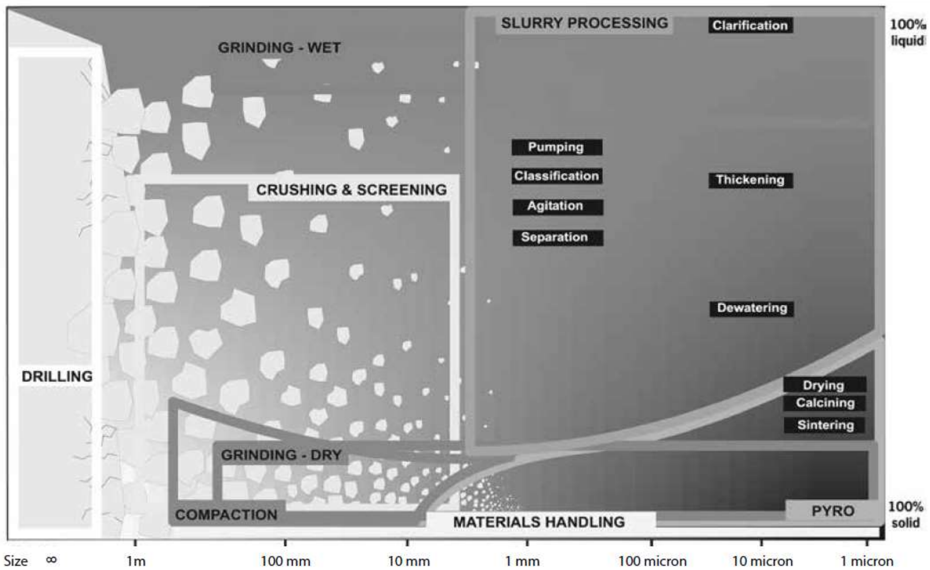
a. o. = And Others

Minerals by value

Minerals

- **Industrial minerals**
  - **Abrasives**: Corundum, Quartz, Diamond a.o.
  - **Glass**: Quartz, Feldspar, Calcite, Dolomite a.o.
  - **Plastic**: Calcite, Kaolin, Talc, Wollastonite, Mica a.o.
  - **Ceramics**: Quartz, Kaolin, Feldspar a.o.
  - **Fertilisers**: Phosphate, Potash, Calcite, Dolomite a.o.
  - **Fillers and pigment**: Barite, Bentonite, Calcite, Dolomite, Feldspar, Talc a.o.
  - **Refractories**: Wollastonite, Calcite, Dolomite, Corundum a.o.
- **Mineral fuels**
  - Coals, Oil shale, (Oil sand)
- **Rock**
  - **Aggregate, sand & gravel**: Concrete ballast, Asphalt ballast, Rock fill, Industrial sand, a.o.
- **Ores**
  - *Non-ferrous*
    - **Base metals**: Copper, Lead, Zinc a.o.
    - **Light metals**: Aluminium, Magnesium, Titanium
    - **Precious metals**: Gold, Silver, Platinum a.o.
    - **Rare metals**: Uranium, Radium, Beryllium a.o.
  - *Ferrous alloy*
    - **Alloying metals**: Chromium, Vanadium, Molybdenum, Tungsten, a.o.
  - *Ferrous*
    - **Iron**

The process frame of minerals



Mineral processing and hardness

- All deposits of minerals, rock or ores have different hardness depending on the chemical composition and the geological environment.

Mohs numbers are a simple classification:

1.	Talc	Crushed by a finger nail	Graphite, Sulphur, Mica, Gold
2.	Gypsum	Scratched by a finger nail	Dolomite
3.	Calcite	Scratched by an iron nail	Magnesite
4.	Fluorite	Easily scratched by a knife	Magnetite
5.	Apatite	Scratched by a knife	Granite, Pyrite
6.	Feldspar	Hardly scratched by a knife	Basalt
7.	Quartz	Scratches glass	Beryl
8.	Topaz	Scratched by quartz	
9.	Corundum	Scratched by a diamond	
10.	Diamond	Cannot be scratched	

In 1813 an Austrian geologist, Mr. Mohs, classified minerals according to their individual hardness.

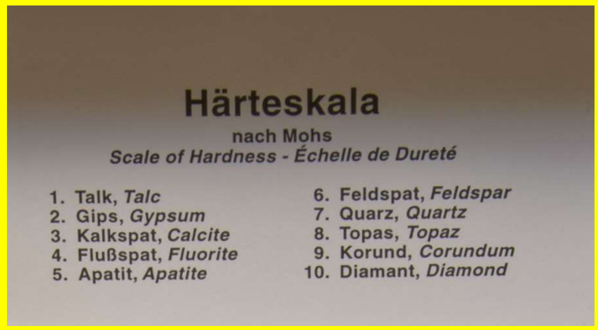
Mineral processing and hardness

Friedrich Mohs

Friedrich Mohs, 1832

Born	29 January 1773 Gernrode, Holy Roman Empire
Died	29 September 1839 (aged 66)
Alma mater	University of Halle
Known for	Mohs scale of mineral hardness
	Scientific career
Fields	geology, mineralogy

The **Mohs scale of mineral hardness** (/moʊz/) is a qualitative ordinal scale characterizing scratch resistance of various minerals through the ability of harder material to scratch softer material. Created in 1812 by German geologist and mineralogist Friedrich Mohs, it is one of several definitions of hardness in materials science, some of which are more quantitative.



Mineral processing and hardness

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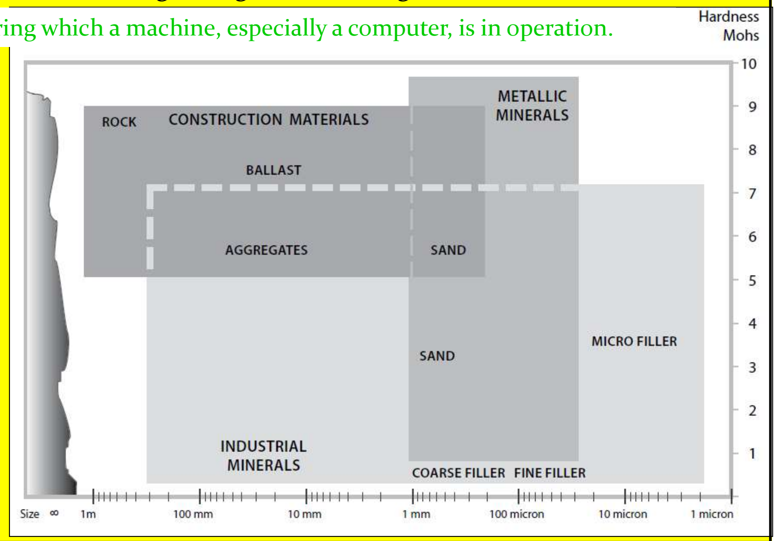
Mineral processing and hardness

Mineral processing and hardness

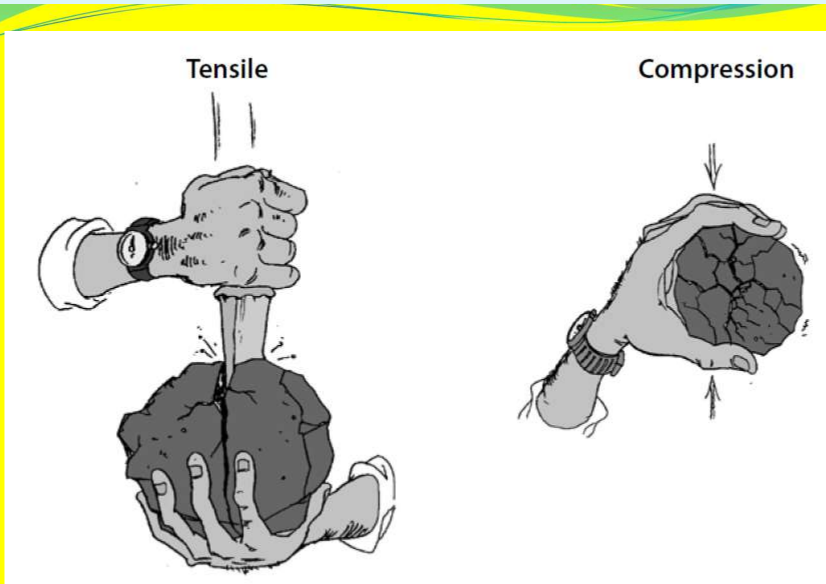
Size and hardness

- All operations have different process environments due to mineral hardness and size range. It is important to know in which "range" we are operating as this will affect many process parameters, (wear rate, uptime, operation costs etc.). Size and hardness together give interesting information.

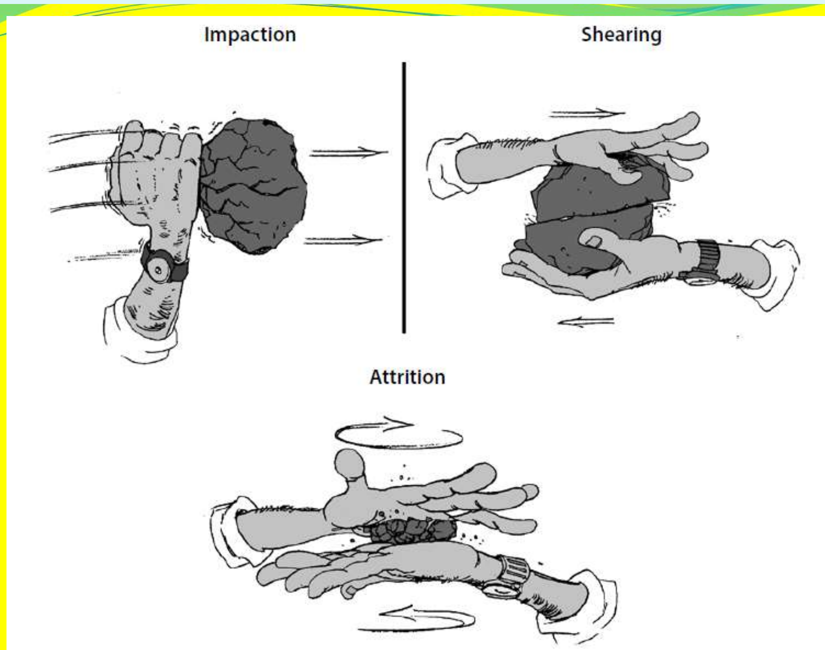
Uptime: time during which a machine, especially a computer, is in operation.



The stress forces of rock mechanics



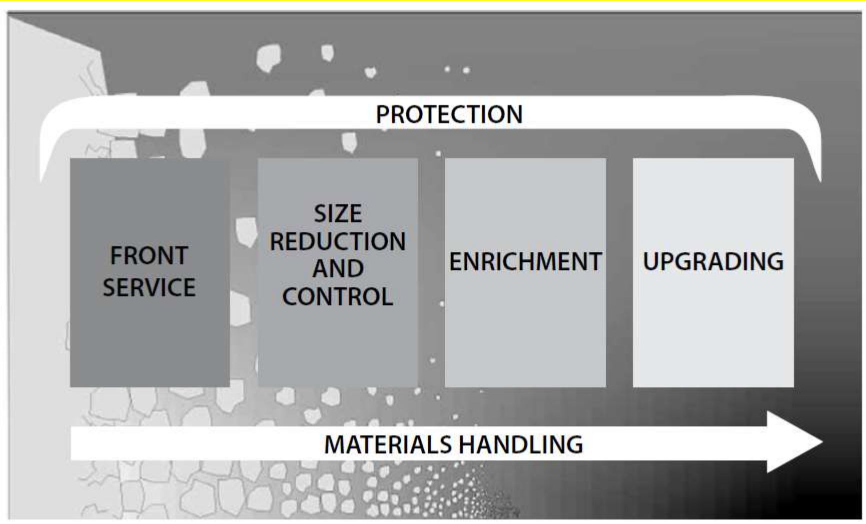
The stress forces of rock mechanics



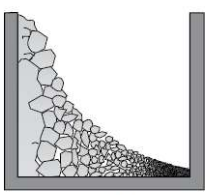
Operation stages

Front service:	Starting point of mineral processing
Size reduction & control:	Processes to produce requested size distributions from feed material
Enrichment:	Processes to improve value of minerals by washing and/or separation
Upgrading:	Processes to produce requested end products from value and waste minerals.
Materials handling:	Operations for moving the processes forward with a minimum of flow disturbances
Protection:	Measures to protect the process environment above from wear and emissions of dust and sound

Operation stages

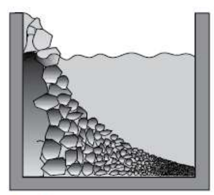


Operation – Dry or wet ?



Dry processing

- When no water is needed for processing
- When no water is allowed for processing



Wet processing

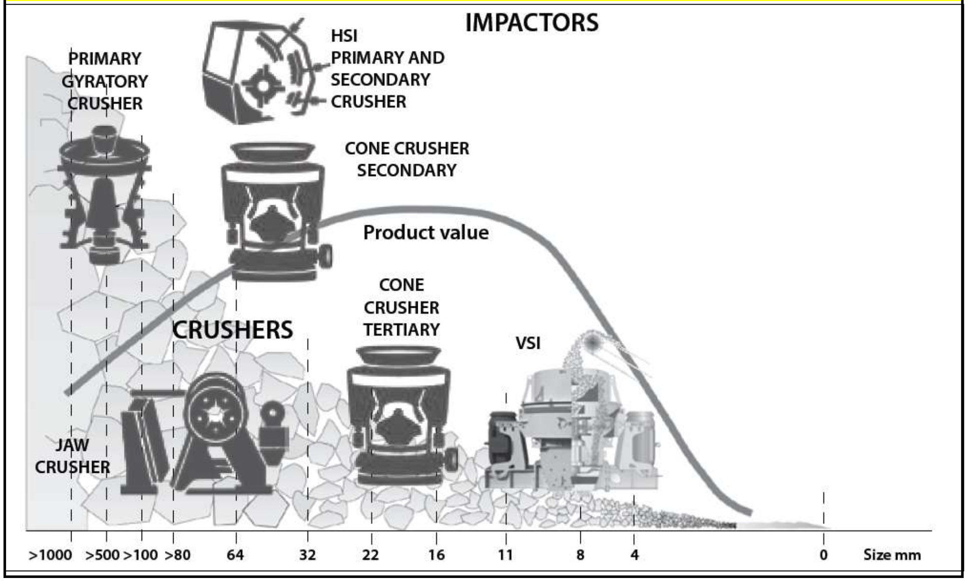
In all other cases due to:

- Better efficiency
- More compact installation
- No dusting

Note! Wear rate is generally higher in wet processing!

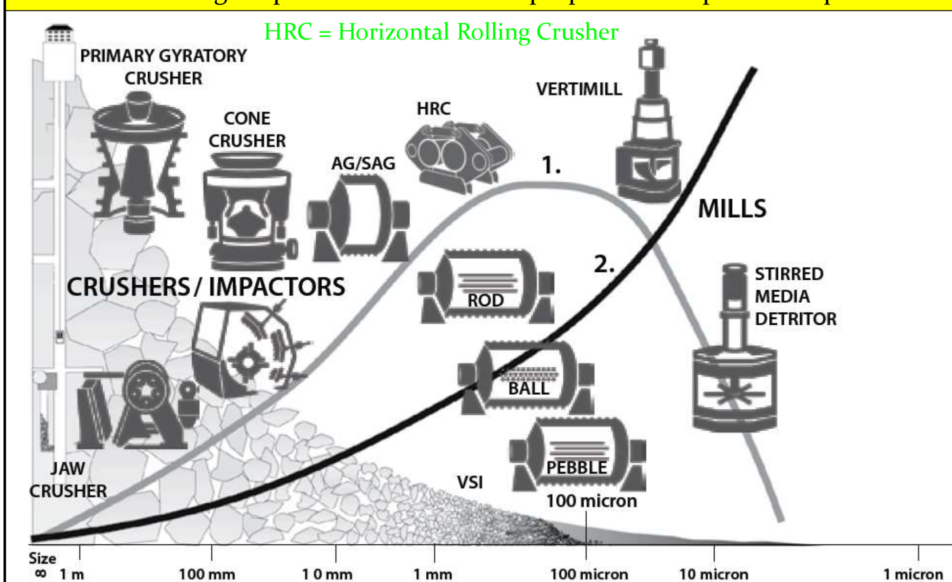
Size reduction

- ❑ Crushing of rock and minerals
- ❑ HSI = Horizontal Shaft Impactor & VSI = Vertical Shaft Impactor



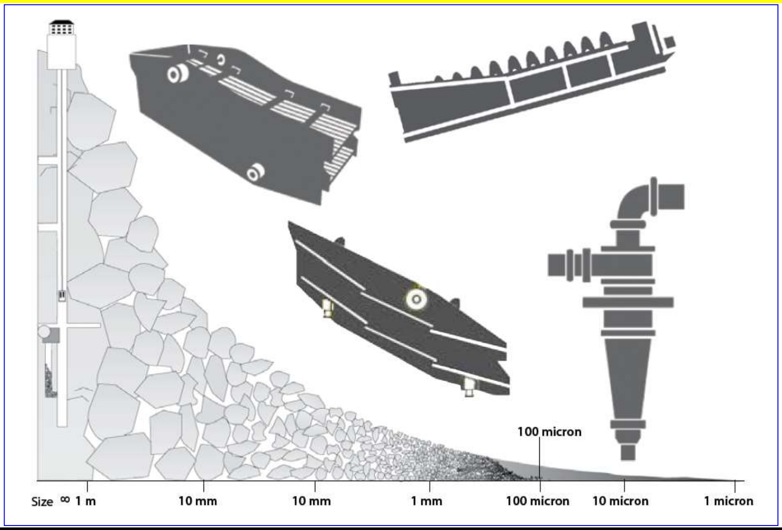
Crushing and grinding of ore and minerals

- ❑ The equipment shown below is a general application range.
- ❑ The actual range depends on the material properties and process requirements.



Size control

- ❑ Size control is the tool for improvement of the size fractions in the process stages and in the final products.
- ❑ For the coarser part of the process, screens are used (in practice above 1-2 mm).
- ❑ In the finer part we have to use classification with spiral classifiers.

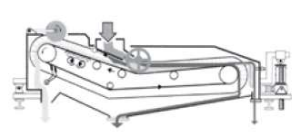


Enrichment – Washing

Washing using

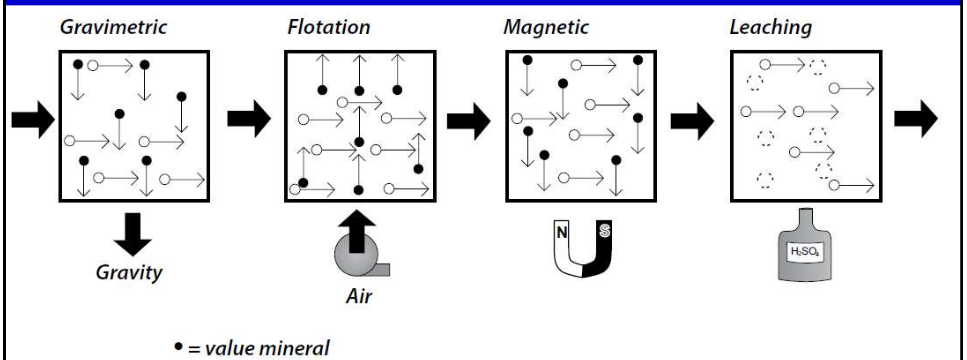
Wet screens* Scrubbers* Attrition cells* Gravity beds*



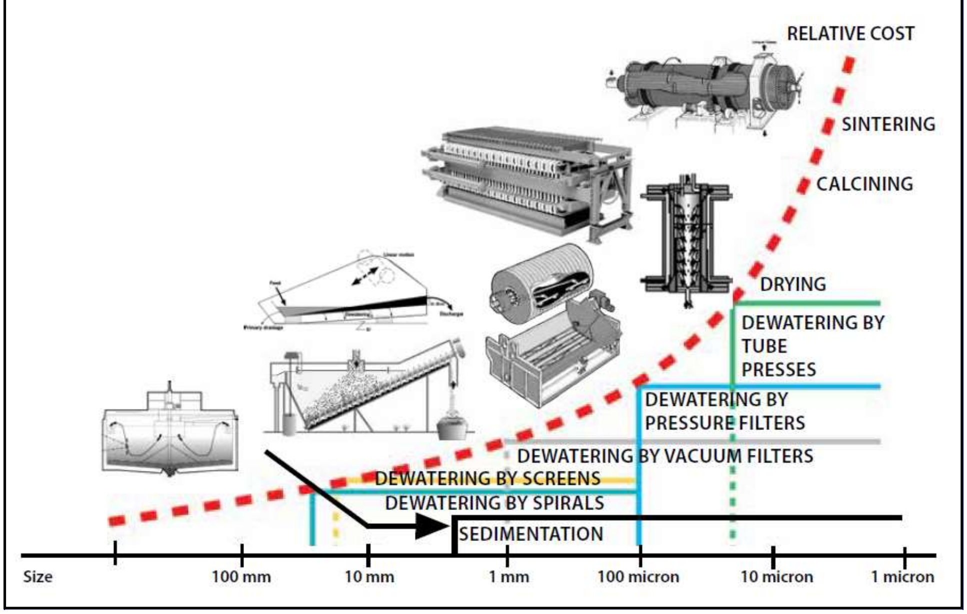
Enrichment – Separation

- Most value minerals (both metallic and industrial) are priced by their purity.
- After liberation by size reduction and size control all minerals are free to be separated from each other.



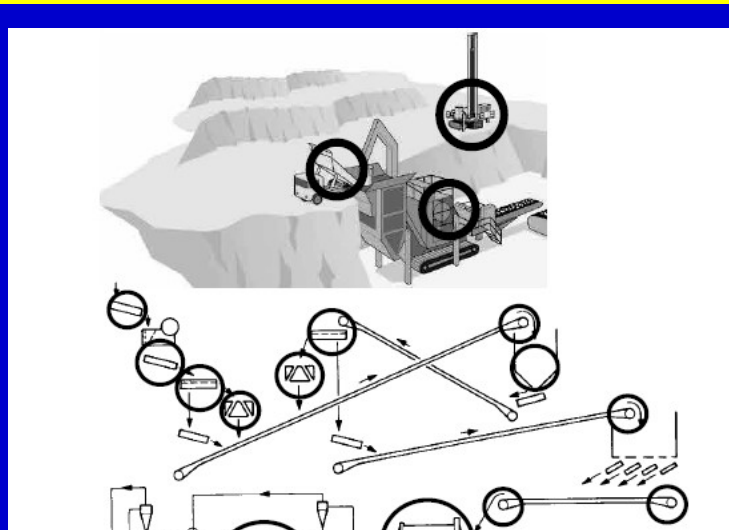
Upgrading

- Upgrading by methods

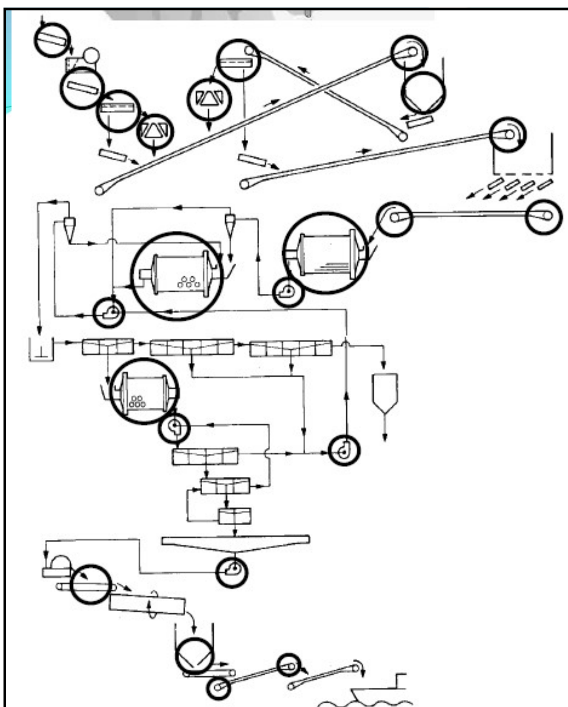


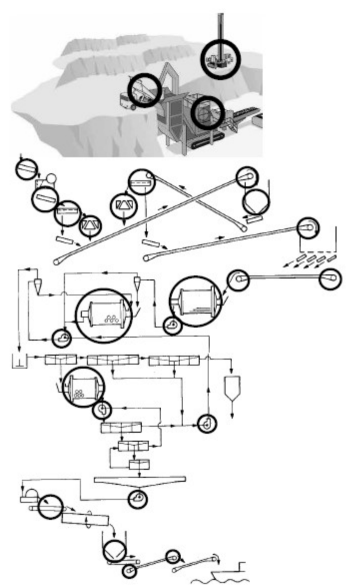
Wear in operation

- Whenever energy in any form penetrates rock, ore or mineral, wear will appear.

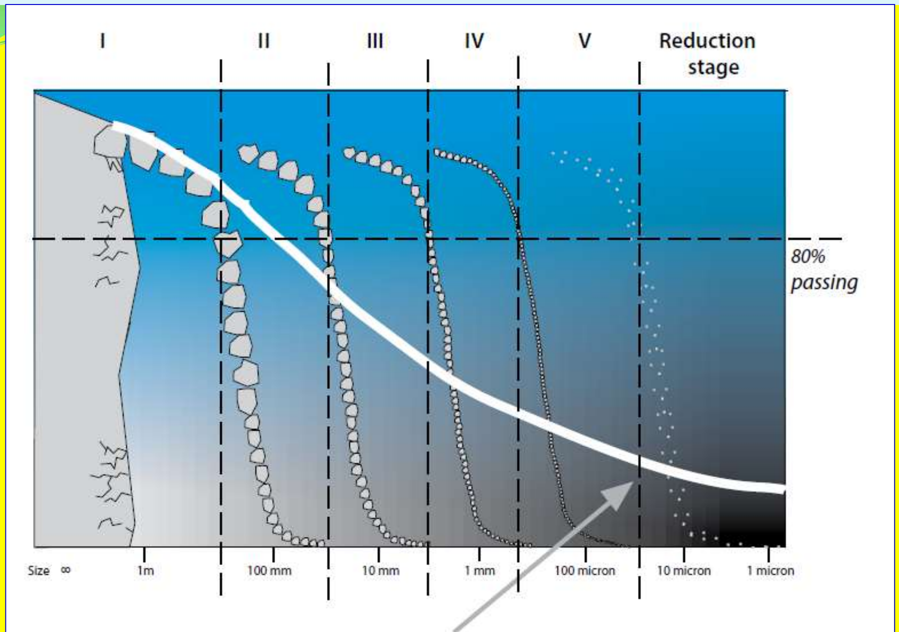


Wear in operation





The size reduction process



Size reduction behaviour of minerals - by nature

Size reduction

- ❑ Feed material
- ❑ All operations in size reduction, both crushing and grinding are of course determined by the **feed characteristics** of the minerals (rock/ore) moving into the circuit.
- ❑ The key parameters we need are the "crushability or grindability", also called **work index** and the "wear profile", called **abrasion index**.
- ❑ Values for some typical feed materials from crushing of rocks, minerals and ore are tabulated below.

Size reduction

Impact Work Index W_i kWh/sh.ton				Abrasion index = A_i			
Material	**Wi value**			**Material**	**Ai value**		
Basalt	20	±	4	Basalt	0,200	±	0,20
Diabase	19	±	4	Diabase	0,300	±	0,10
Dolomite	12	±	3	Dolomite	0,010	±	0,05
Iron-ore, Hematite	13	±	8	Iron-ore, Hematite	0,500	±	0,30
Iron-ore, Magnetite	12	±	8	Iron-ore, Magnetite	0,200	±	0,10
Gabbro	20	±	3	Gabbro	0,400	±	0,10
Gneiss	16	±	4	Gneiss	0,500	±	0,10
Granite	16	±	6	Granite	0,550	±	0,10
Greywacke	18	±	3	Greywacke	0,300	±	0,10
Limestone	12	±	3	Limestone	0,001	–	0,03
Quartzite	16	±	3	Quartzite	0,750	±	0,10
Porphyry	18	±	3	Porphyry	0,100	–	0,90
Sandstone	10	±	3	Sandstone	0,600	±	0,20
Syenite	19	±	4	Syenite	0,400	±	0,10

INFLUENCING

- Size reduction
- Energy requirement
- Machine status

INFLUENCING

- Wear rate

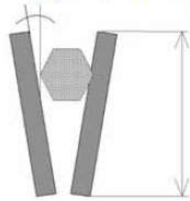
Regarding Work Index (Bond) for grinding

Reduction ratio

- As seen above all size reduction operations are performed in stages.
- All equipment involved, crushers or grinding mills have different relation between feed and discharge sizes. This is called **reduction ratio**. Typical values below.
- Note! High reduction ratio is generally inefficient. For maximum energy efficiency, we recommend multiple stages of grinding.

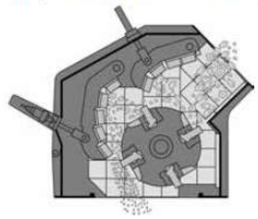
Reduction ratio

Compression crushers



Jaw 3-4
Gyratory 3-5
Cone 3-5

Impactors (horizontal type)

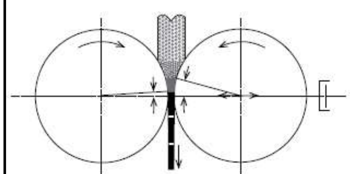


4-8

Impactors (vertical type)

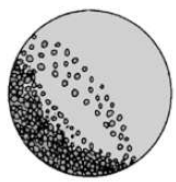
2-5

High pressure grinding rolls



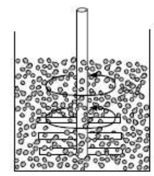
25

Grinding mills (tumbling type)



Rod 100
Ball 1000
AG & SAG 5000

Stirred grinding mills

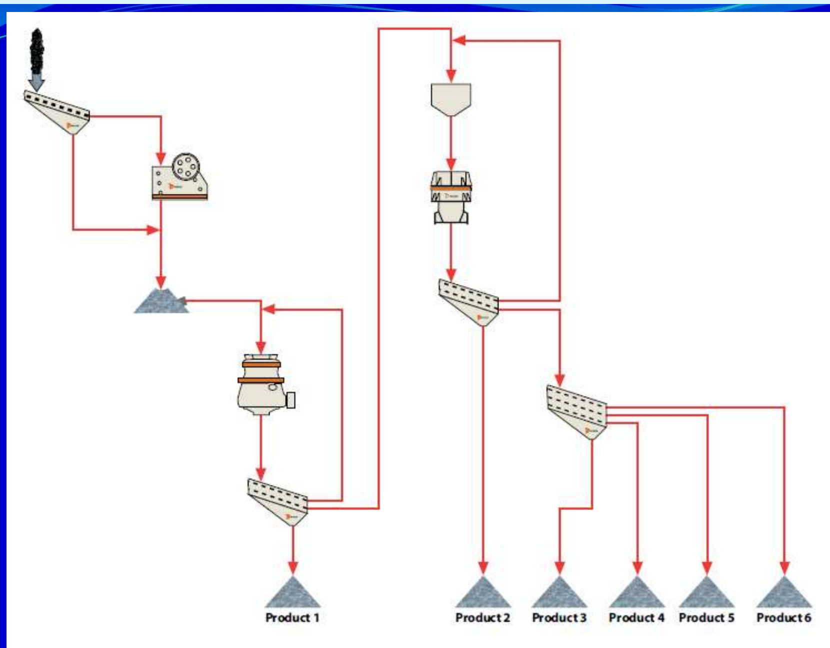


100

Crushing of rock and gravel

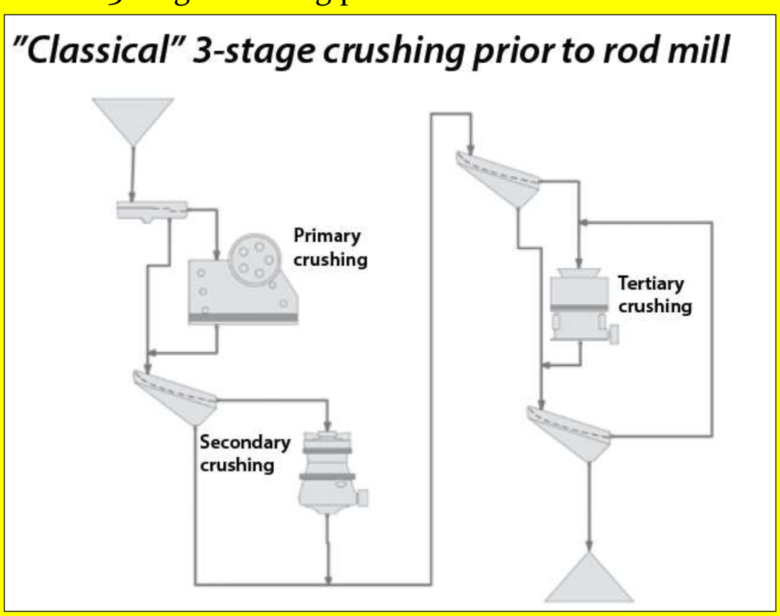
- In the ballast business you are normally paid for short fractions of relatively coarse material with the correct size and shape.
- Most of the ballast for concrete and asphalt is in the 4 - 18 mm (1/5 - 3/4”) interval.
- In order to produce the correct shape and keep over- and under sizes as low as possible this **crushing must be done in several stages (3 - 5)**.

Crushing of rock and gravel



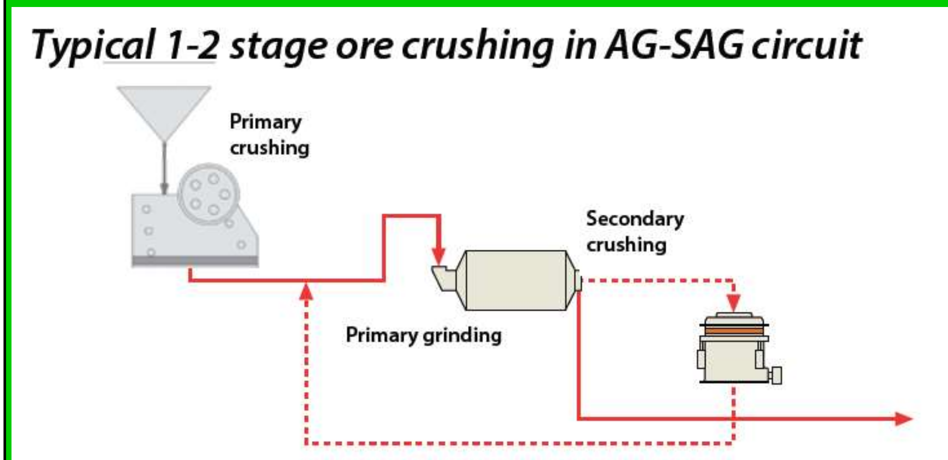
Crushing of ore and minerals

- ”Classical” 3-stage crushing prior to rod mill



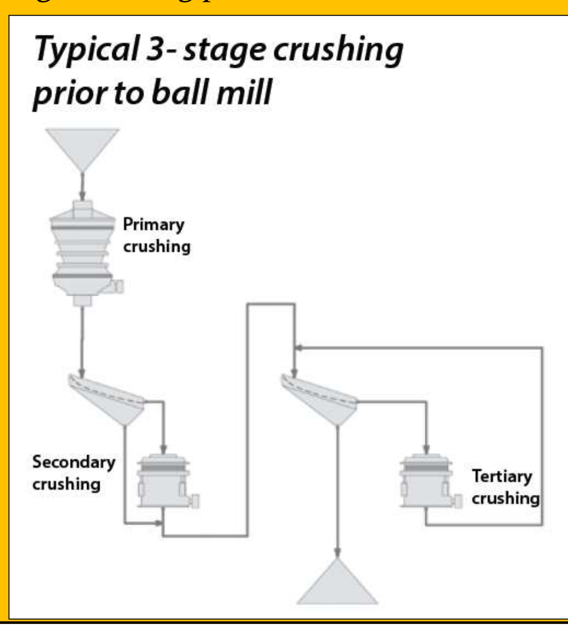
Crushing of ore and minerals

- ❑ Typical 1-2 stage ore crushing in AG-SAG circuit



Crushing of ore and minerals

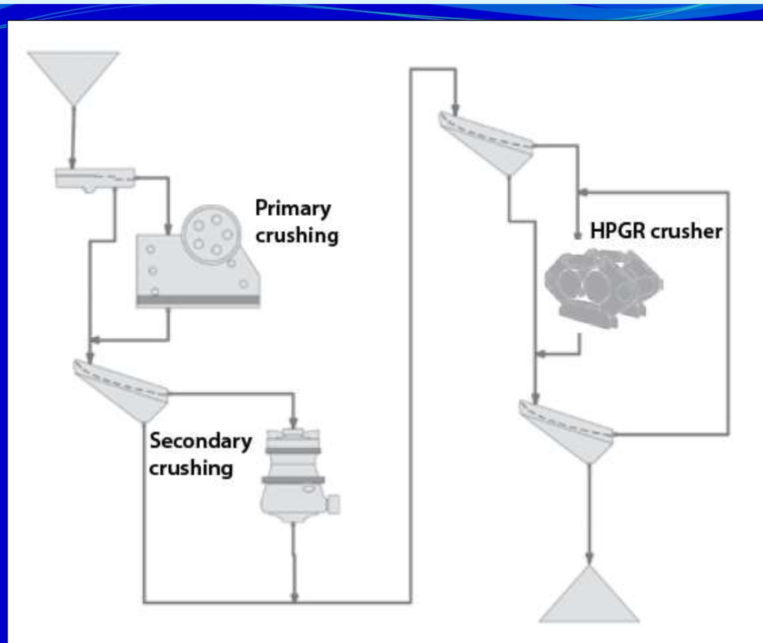
- ❑ Typical 3- stage crushing prior to ball mill



Crushing of ore and minerals

- ❑ 3-stage crushing utilizing an HPGR prior to a rod mill or ball mill
- ❑ Another option is including HPGRs in the crushing circuit.
- ❑ Commons circuits include utilizing HPGRs as a:
  - ➢ tertiary crusher, followed by a ball mill or VERTIMILL®
  - ➢ quaternary crusher, followed by a ball mill or VERTIMILL®
  - ➢ pebble crusher in a SABC circuit

Crushing of ore and minerals



Crushing – Calculation of reduction ratio

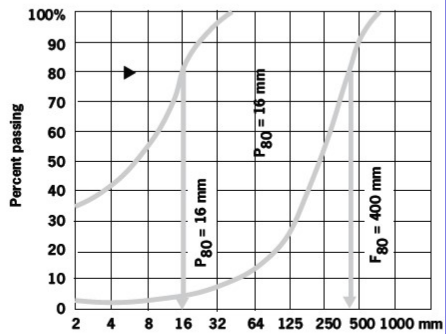
Feed material size: F_{80} = 400 mm
Blasted rock, 80% smaller than 400 mm

Product size: P_{80} = 16 mm
Road aggregates or rod mill feed 80% smaller than 16 mm

Total reduction ratio (R) F_{80}/P_{80} 400/16 = **25**

Reduction ratio in the primary crushing stage R1 = **3**
Reduction ratio in the secondary crushing stage R2 = **4**

Total in 2 crushing stages gives R1xR2 = 3x4 = **12**



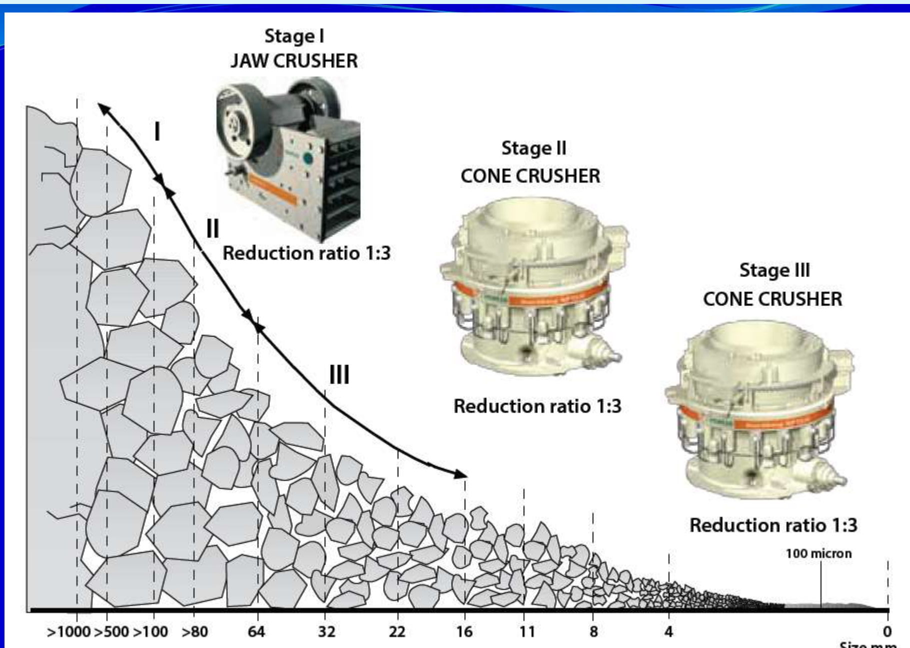
**As we have to use three stages, we can reduce the reduction ratio a bit in every stage, giving more flexibility to the circuit!*

This is not sufficient. We need a third crushing stage.*

For example:	Reduction first stage	R1 = 3
	Reduction second stage	R2 = 3
	Reduction third stage	R3 = 3

Together these three stages give R1xR2xR3 = 3x3x3 = **27** = sufficient reduction

Crushing – Calculation of reduction ratio



Selection of crushers

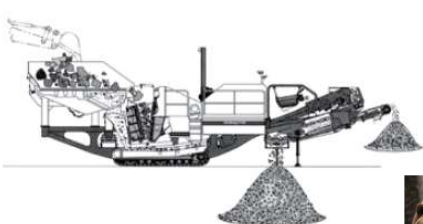
Stationary crushers – surface and underground

Primary Gyratory

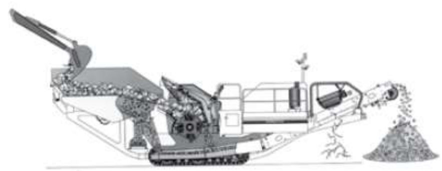
Jaw

Impact

Mobile Crushers



Jaw + grizzly



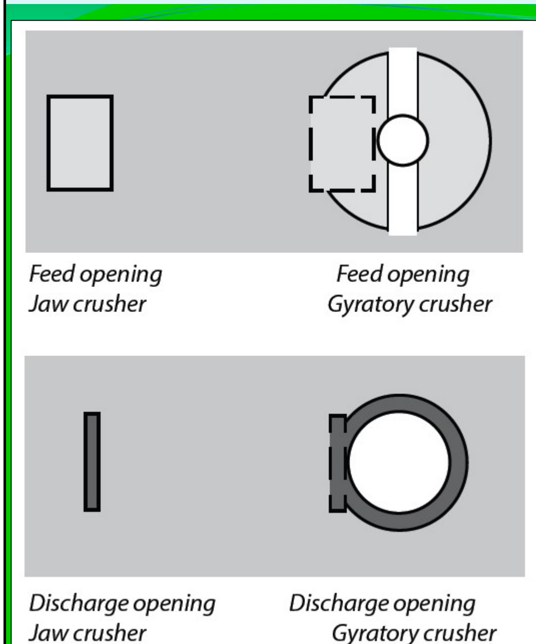
Impact + grizzly

Primary crusher – Type

- For soft feed and non-abarasive feed (low Bond work index) a Horizontal Shaft Impactor (HSI) is an option if the capacity is not too high.
- For harder feed there is a choice between a gyratory or a jaw crusher, see below.
- Note: HSI can be used only if the abrasion index is lower and the plant does not mind fines production. Otherwise, a jaw crusher is preferred for lower capacity aggregate plants.
- **Rule 1:** Always use a jaw crusher if you can, jaws are the least capital cost.
- **Rule 2:** For low capacity use jaw crusher and hydraulic hammer for oversize.
- **Rule 3:** For high capacities (800-1500 tph) use jaw crusher with big intake opening.
- **Rule 4:** For very high capacities (1200+ tph) use gyratory crusher.

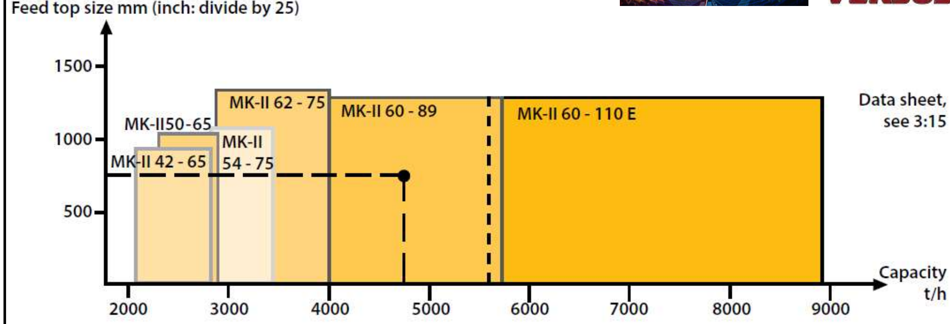
Hydraulic Hammer

Primary crusher – Type

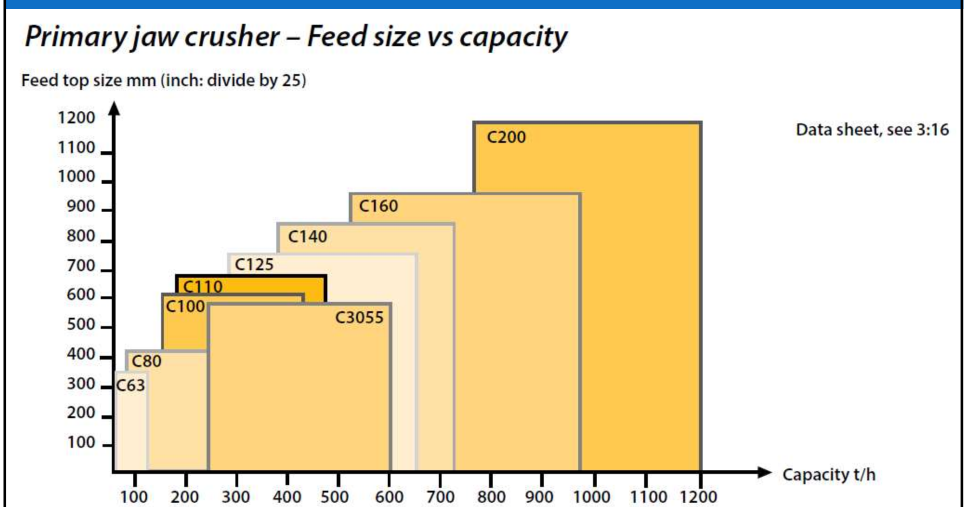


Primary crusher – Sizing

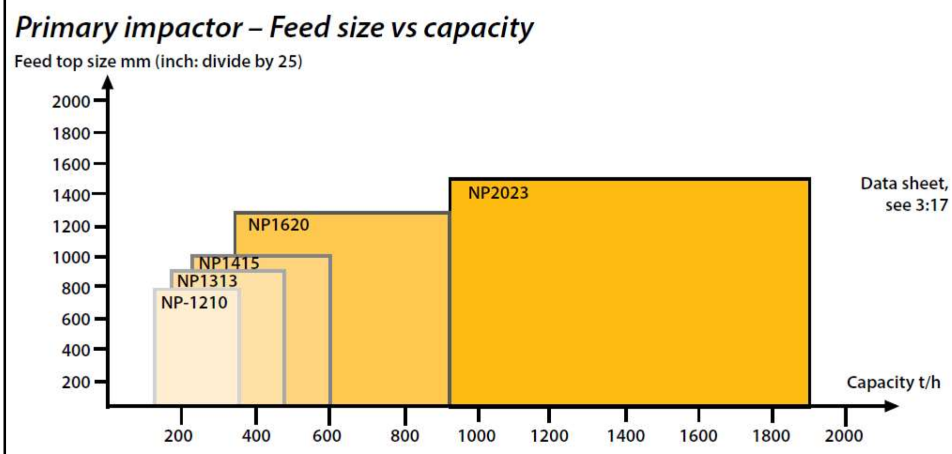
- ❑ Crushers are normally sized from top size of feed. At a certain feed size, knowing the capacity, we can select the correct machine, see below.



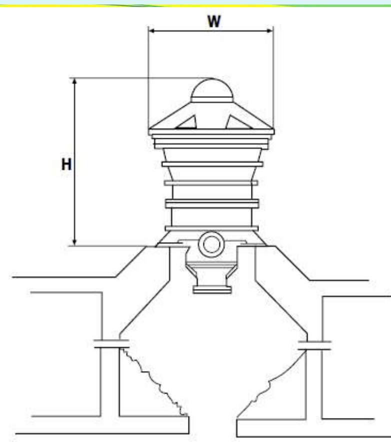
Primary crusher – Sizing



Primary crusher – Sizing

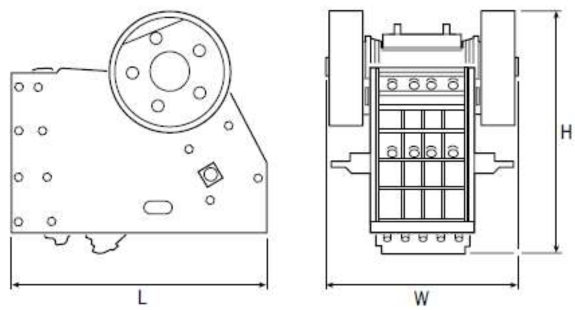


Gyratory crusher – SUPERIOR® MK-II Primary



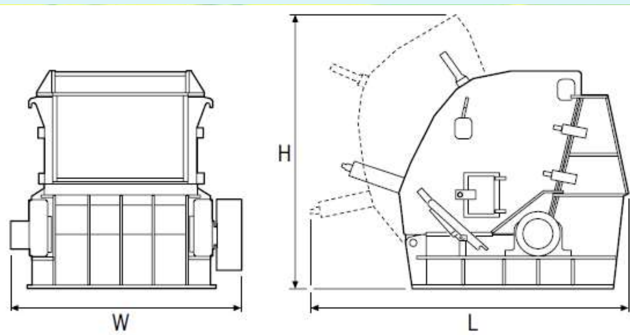
Type	H mm (inch)	W mm (inch)	Weight mt (U.S. t)	Max. power kW (Hp)
MK-II 42-65	4807 (189.3)	3937 (155.0)	120 (132)	375 (500)
MK-II 50-65	5513 (217.0)	4458 (175.5)	153 (168)	375 (500)
MK-II 54-75	5957 (234.5)	4928 (194.0)	242 (266)	450 (600)
MK-II 62-75	6633 (261.1)	5574 (219.4)	299 (328)	450 (600)
MK-II 60-89	7474 (294.3)	5588 (220.0)	398 (438)	600 (800)
MK-II 60-110E	7518 (296.0)	6197 (244.0)	553 (609)	1200 (1600)

Jaw crusher – C series



Type	H mm (inch)	L mm (inch)	W mm (inch)	Weight mt (US ton)	kW/Hp Max. power
C 63	1 600 (63)	1 950 (77)	1 390 (55)	5 (6)	45/60
C 80	1 700 (67)	2 020 (80)	1 565 (62)	7 (8)	75/100
C 100	2 400 (95)	2 880 (113)	2 250 (89)	18 (20)	110/150
C 105	2 050 (81)	2 630 (104)	1 920 (76)	13 (14)	110/150
C 110	2 670 (105)	2 830 (112)	2 385 (94)	23 (25)	160/200
C 125	2 900 (114)	3 370 (133)	2 690 (106)	33 (36)	160/200
C 140	3 060 (121)	3 645 (144)	2 890 (114)	41 (45)	200/250
C 145	3 330 (131)	3 855 (152)	2 870 (113)	49 (54)	200/250
C 160	3 550 (140)	4 200 (165)	3 180 (125)	63 (69)	250/300
C 200	4 220 (166)	4 870 (192)	3 890 (153)	107 (118)	400/500
C 3055	2 400 (95)	2 920 (115)	2 550 (100)	24 (26)	160/200

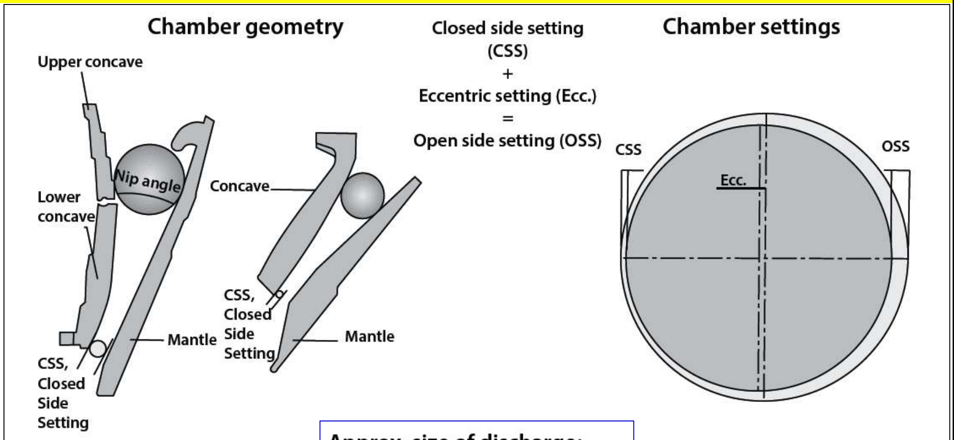
Impact crusher – NP series



Type	H mm (inch)	L mm (inch)	W mm (inch)	Weight mt (US ton)	kW/Hp Max. power
NP 1110	2 716 (107)	3 487 (137)	2 106 (83)	8 (9)	250/350
NP1213	2 882 (114)	3 875 (153)	2 529 (100)	12 (13)	315/400
NP1315	3 055 (120)	4 030 (159)	2 750 (108)	15 (16)	500 (2x250)/700 (2x350)
NP1520	3 540 (139)	4 703 (186)	3 400 (134)	24 (27)	1200 (2x600)/1600 (2x800)
NP 1313	3 405 (134)	3 396 (134)	2 560 (101)	16 (18)	200/250
NP 1415	3 600 (142)	3 395 (134)	2 790 (110)	20 (22)	250/350
NP 1620	4 400 (173)	3 935 (155)	3 600 (142)	36 (40)	315/400
NP 2023	5 700 (224)	5 040 (198)	4 330 (171)	67 (74)	500 (2x250)/700 (2x350)

Cone crusher – A powerful concept

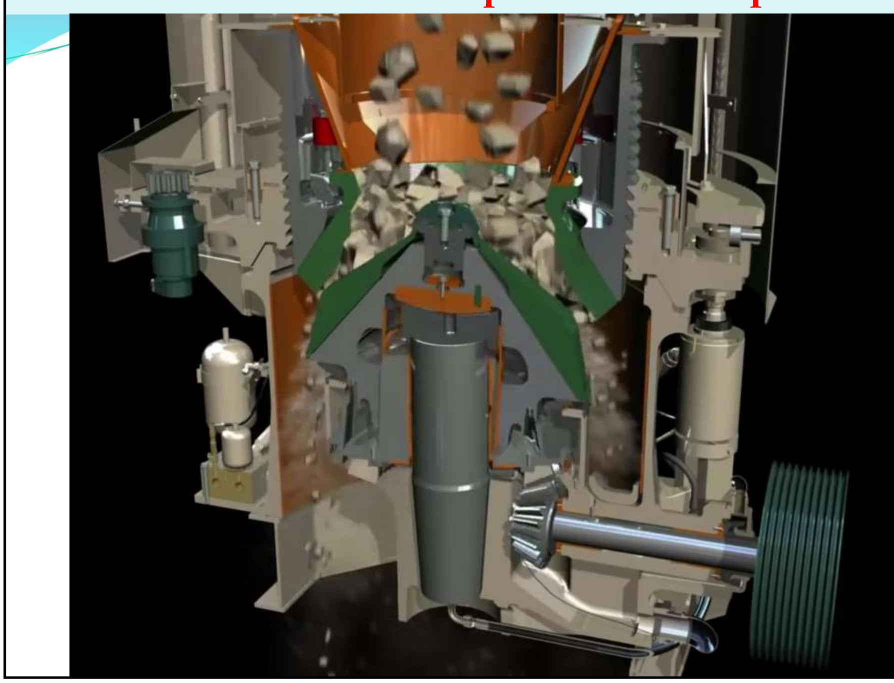
- Compared to other crushers the cone crusher has some advantages making them very suitable for size reduction and shaping downstream of a crushing circuit. Reason is the crushing chamber and the possibilities to change feed and discharge openings during operation.



Approx. size of discharge:

From Cone	70-80%<CSS
From Gyratory	85-95%<OSS

Cone crusher – A powerful concept



Cone crusher – A powerful concept

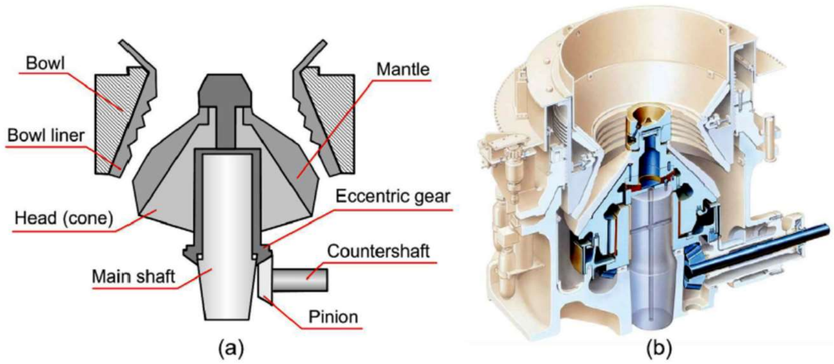


FIGURE 6.8 Cone crusher: (a) functional diagram, and (b) cross section *(Courtesy Metso).*

Cone crusher – A powerful concept

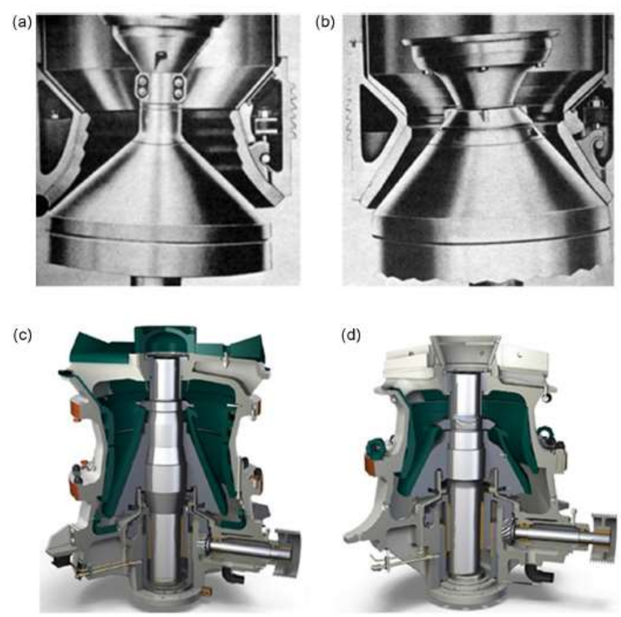
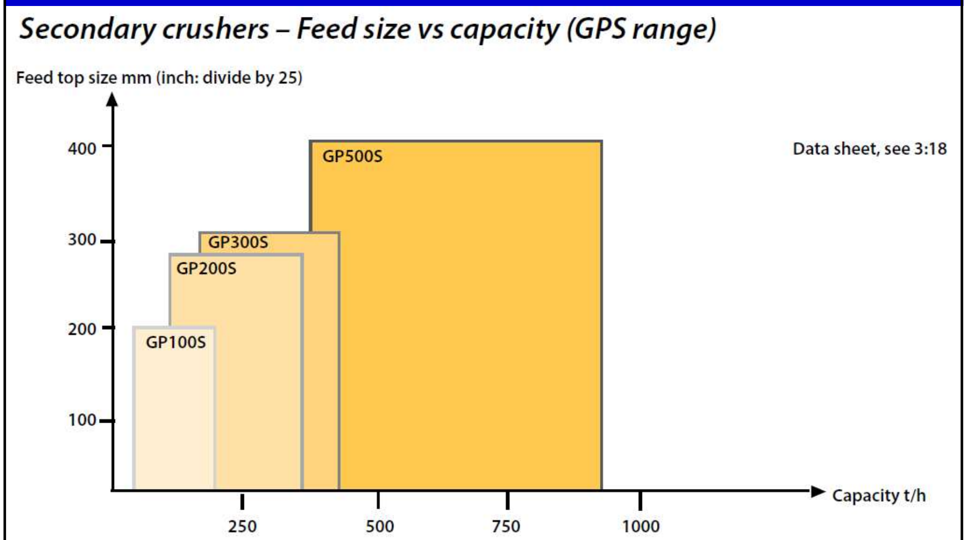


FIGURE 6.9 Cone crushers: original (a) standard, (b) short-head, and modern (c) secondary, and (d) tertiary cone crushers *((c) and (d) Courtesy Metso).*

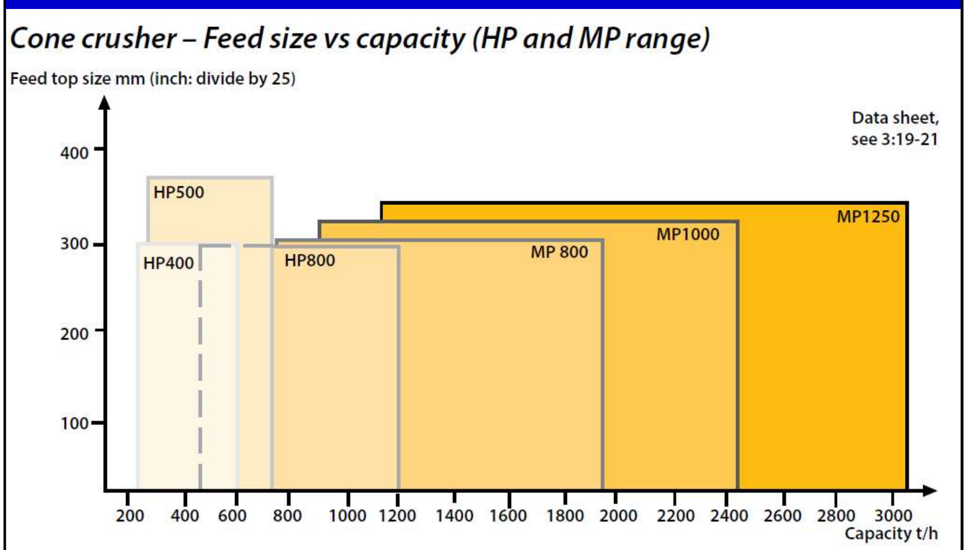
Cone crusher – A powerful concept

Cone crusher – A powerful concept

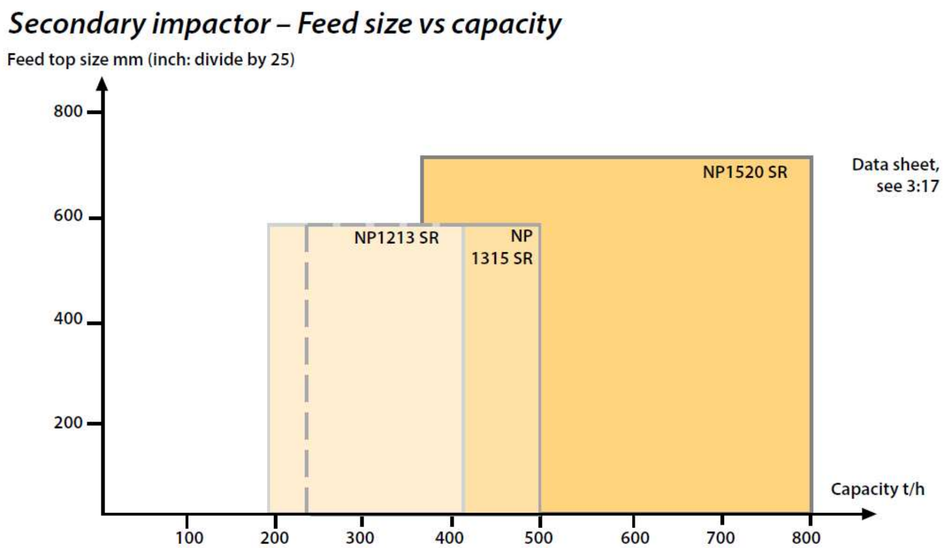
Secondary crushers (Cone) – Sizing



Secondary crushers – Sizing



Secondary crushers – Sizing



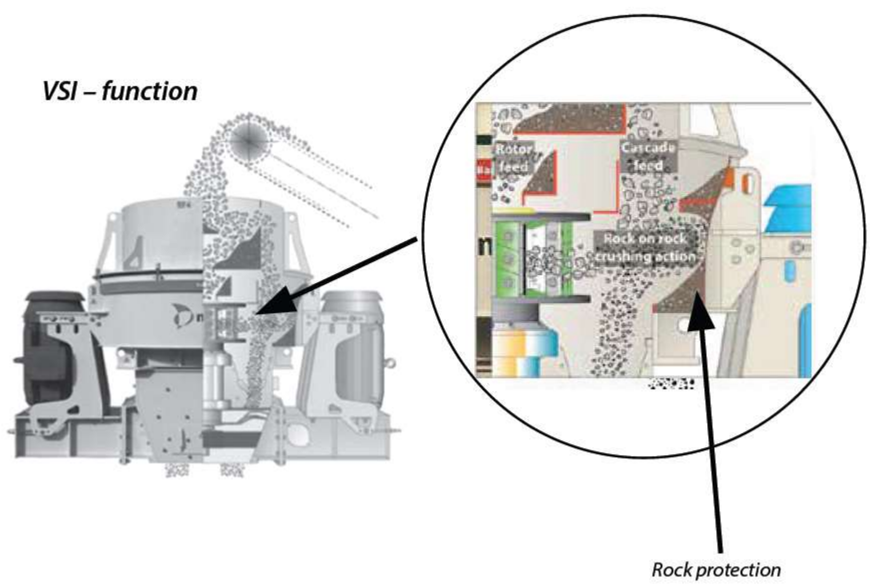
Final crushing stage – More than just crushing

- For many rock and gravel crushing circuits the final crushing stage is of special interest.
- The final sizing and shaping will take place in this stage <u>influencing the value of the final product</u>.
- For hard abrasive rock circuits, Cone crushers, Vertical Shaft Impactors (VSI) or High Pressure Grinding Rolls (HPGRs) can be used.

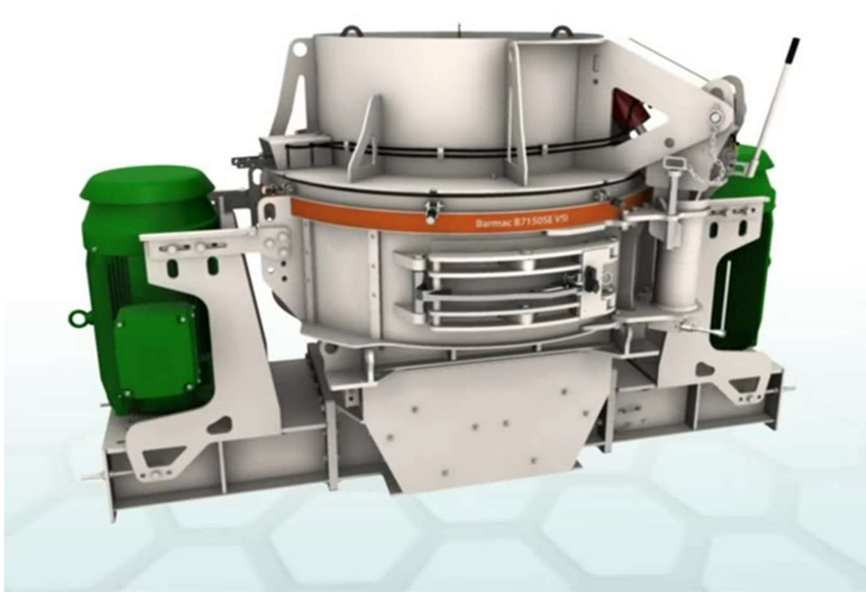
VSI – A rock on rock autogeneous crushing impactor

- Horizontal impactors normally use rock to metal impaction. This means a restriction in crushing circuits with hard feed material, when wear can be dramatically high.
- The VSI Impactor of Barmac type is using a rock-to-rock impaction technology where most of the design is protected by rock, see below. This means that we can use the advantages of the impaction techniques also in hard, abrasive rock operations.
- The crushing action takes place in the "rock cloud" in the crushing chamber, not against the rock protection.

VSI – A rock on rock autogeneous crushing impactor



VSI – A rock on rock autogeneous crushing impactor



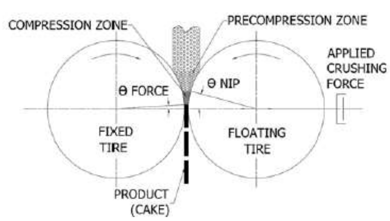
High Pressure Grinding Rolls (HPGRs) - HRC™

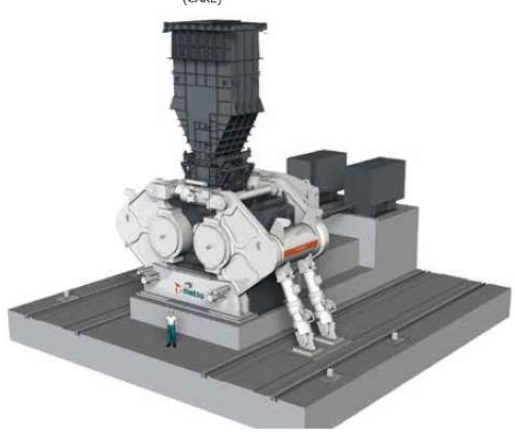
- HPGRs utilize two counter-rotating tires – one fixed and one floating – in order to effectively crush ore.
- Hydraulic cylinders apply very high pressure to the system, causing inter-particle comminution as the feed travels between the two tires.
- The basic operating principle behind HPGRs makes them very energy efficient.

High Pressure Grinding Rolls (HPGRs) - HRC™

- The feed is introduced to the crushing zone, where high pressure is applied to the bed of material in a highly controlled manner.
  - Dry
  - Size reduction through compression, controlled application of pressure – energy efficient
  - Open or closed circuit
  - Flexible operating parameters (speed and pressure)
  - No use of grinding media
  - Short retention time
  - Feed size restricted by operating gap, minus 90 mm depending on unit size
  - Low noise level
  - Low operating cost

High Pressure Grinding Rolls (HPGRs) - HRC™



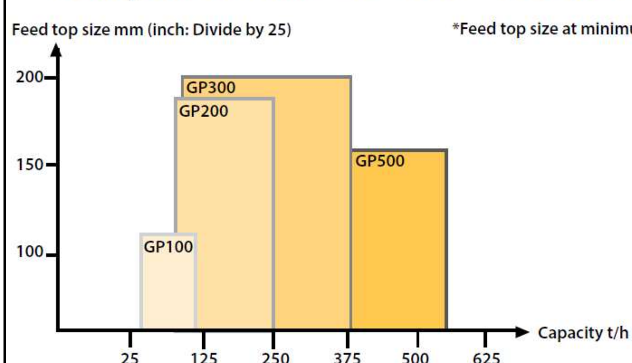


High Pressure Grinding Rolls (HPGRs) - HRC™

Final crusher – Sizing

Tertiary cone crushers – GP series – Feed size vs capacity*

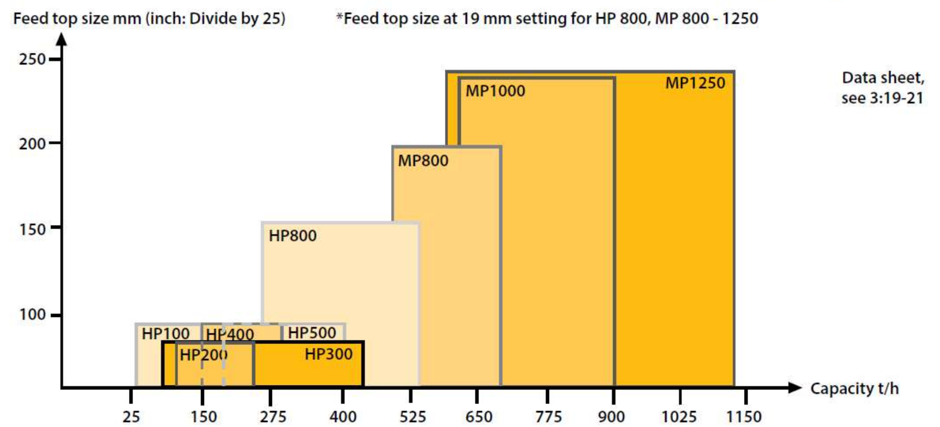
*Feed top size at minimum setting 10 mm and coarse liner profile



Data sheet, see 3:22

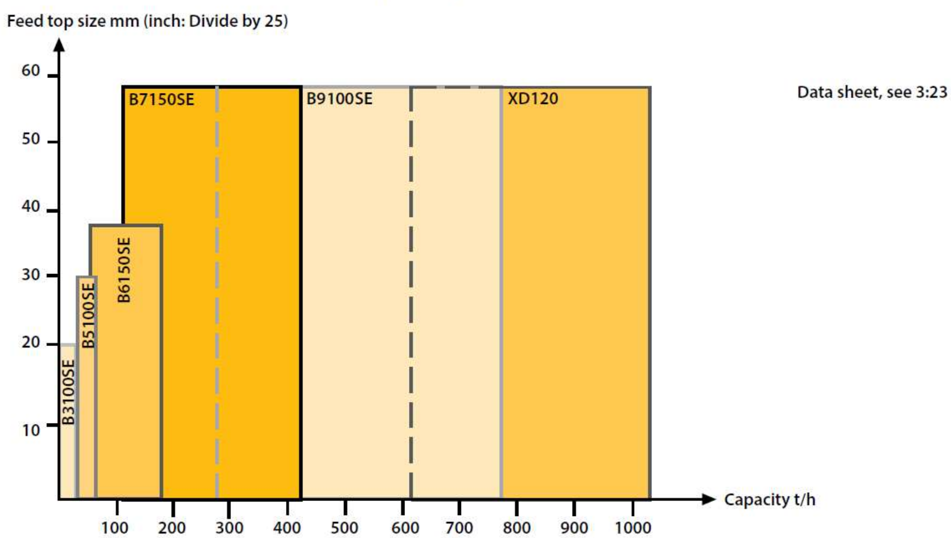
Final crusher – Sizing

Tertiary cone crushers – HP and MP* series – Feed size vs capacity*

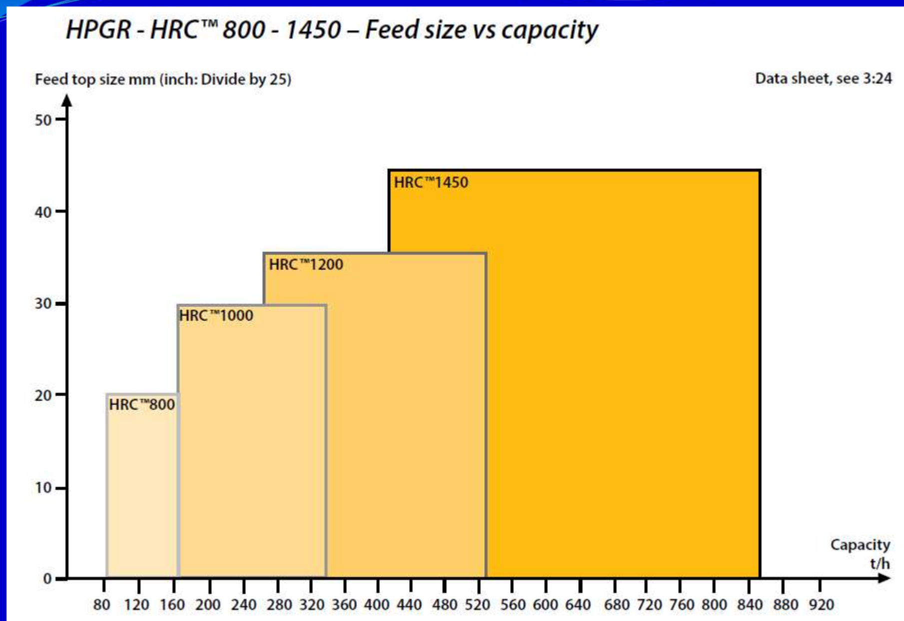


Final crusher – Sizing

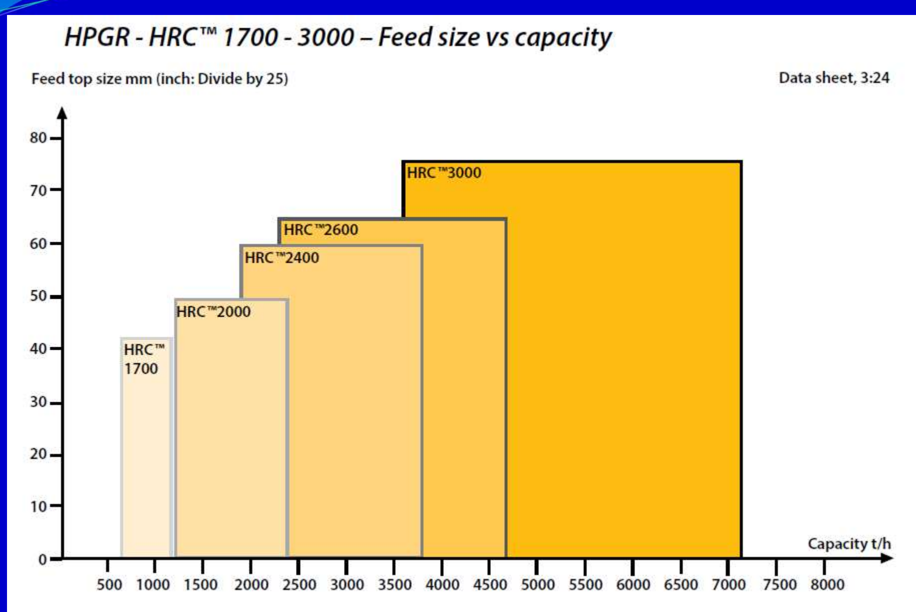
VSI crusher – Feed size vs capacity



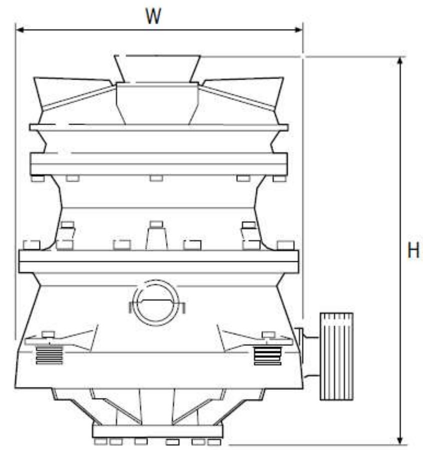
Final crusher – Sizing



Final crusher – Sizing

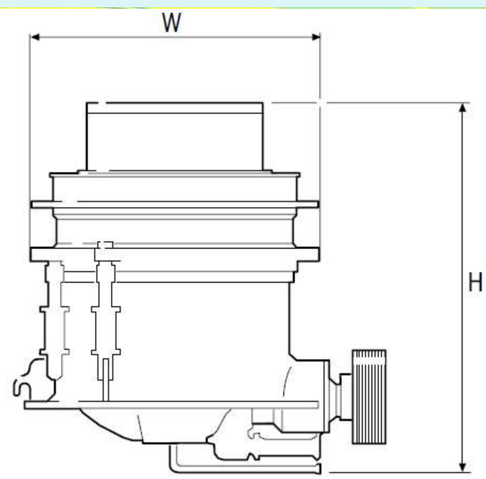


Cone crusher – GPS series



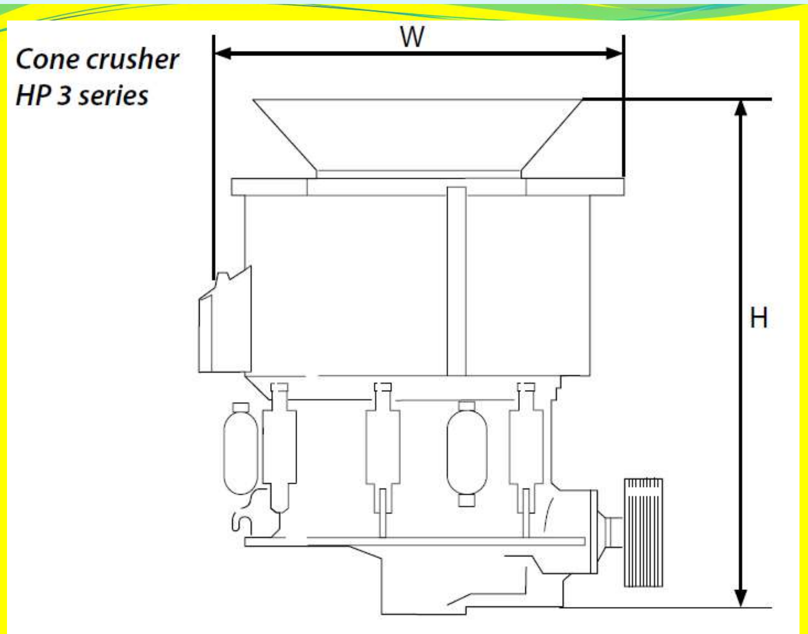
Type	H mm (inch)	W/L mm (inch)	Weight MT (US ton)	kW/Hp Max. power
GP100S	2 328 (92)	1 300 (51)	7 (8)	90/125
GP200S	2 461 (97)	1 745 (69)	10 (11)	160/250
GP300S	2 546 (100)	1 858 (73)	15 (16)	250/350
GP500S	3 227 (127)	2 300 (91)	29 (32)	315/400

Cone crusher – HP series

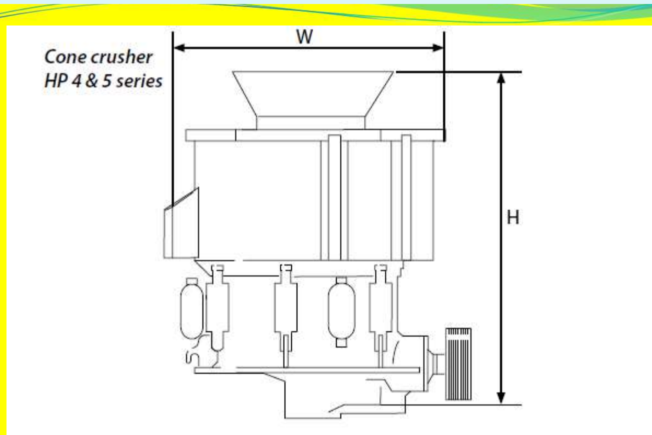


Type	H mm (inch)	W mm (inch)	Weight mt (U.S. t)	Max. power kW (Hp)
HP 800	4 057 (160)	3 490 (137)	69 (76)	600 (800)

Cone crusher – HP 3, 4 and 5 series



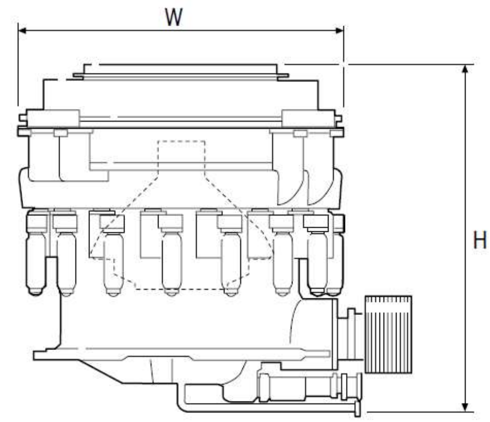
Cone crusher – HP 3, 4 and 5 series



Type	H mm (inch	W mm (inch	Weight kg (lbs)	Weight complete*	Max. power kW (Hp)
HP3	2 817 (111)	2 778 (109	13 280 (29 277)	16 446 (36 257)	220 (300 hp)
HP4	2 549 (100)	2 955 (116)	19 810 (43 586)	23 672 (52 084)	315 (400)
HP5	3 953 (156)	3 854 (152)	33 000 (73 000)	44 500 (98 200)	450 (600)

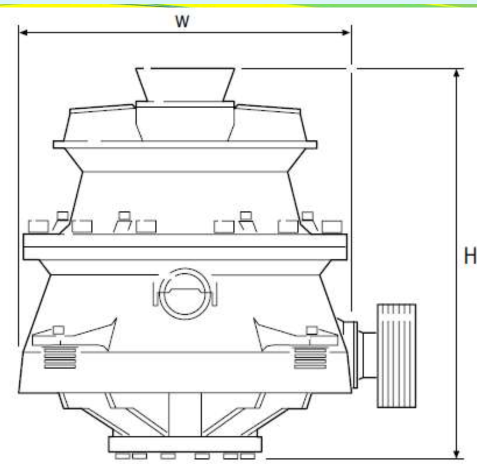
* Complete crusher weight: crusher + subframe, motor, sub frame, covers, feed and discharge arrangement

Cone crusher – MP series



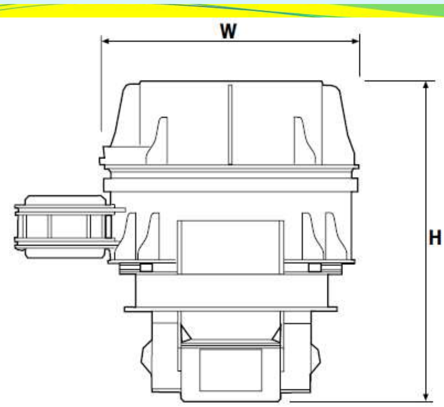
Type	H mm (inch)	W mm (inch)	Weight mt (U.S. t)	Max. power kW (Hp)
MP800	4622 (182.0)	4550 (179.1)	121 (133)	600 (800)
MP1000	4663 (183.6)	5360 (211.0)	151 (166)	750 (1000)
MP1250	4663 (183.6)	5360 (211.0)	153 (168)	900 (1250)

Cone crusher – GP series



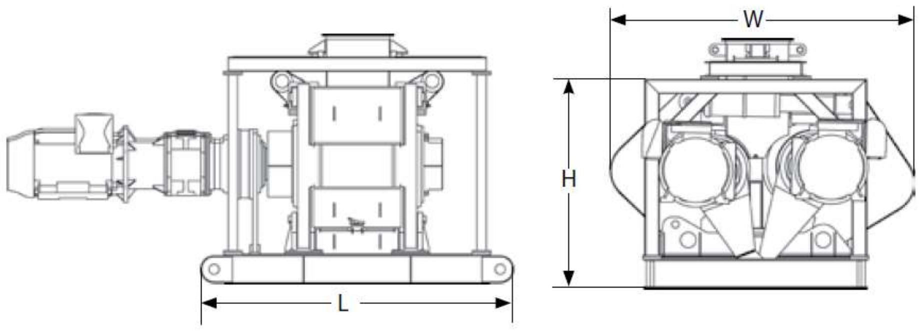
Type	H mm (inch)	W/L mm (inch)	Weight MT (US ton)	kW/Hp Max. power
GP100	2 038 (80)	1 300 (51)	5 (6)	90/124
GP200	2 230 (84)	1 735 (68)	8 (9)	110/160
GP300	2 181 (86)	1 860 (73)	12 (13)	250/300
GP500	2 573 (101)	2 240 (88)	21 (23)	300/400

Vertical shaft impactor (VSI)



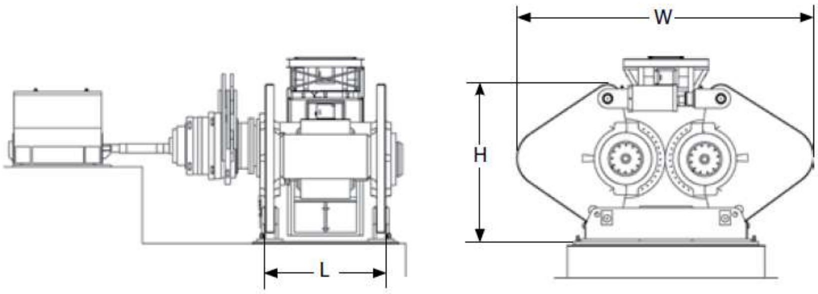
Type	H mm (Inch	W mm (Inch	Weight MT (US ton)	kW/Hp Max. power
B3100SE	1 171 (46)	940 (37)	0,9 (1)	15/20
B5100SE	1 705 (67)	1 435 (56)	2,7 (3)	55/75
B6150SE	2 189 (86)	1 870 (74)	4,5 (5)	150/20
B7150SE	2 464 (97)	2 220 (87)	10 (11)	300/400
B9100SE	2 813 (111)	2 434 (96)	12 (13)	600/800
XD120	4 211 (166)	3 110 (122)	21 (23)	800/1075

High Pressure Grinding Rolls (HPGRs) - HRC™



Model	Tire dimensions mm	Max. motor power kW	Max. motor power HP	H mm (inch)	L mm (inch)	W mm (inch)
HRC™800	730 x 500	2 x 132 kW	2 x 177 HP	2400 (94)	3700 (146)	2700 (106)
HRC™1000	1000 x 625	2 x 260 kW	2 x 349 HP	2700 (106)	3520 (139)	3500 (138)

High Pressure Grinding Rolls (HPGRs) - HRC™



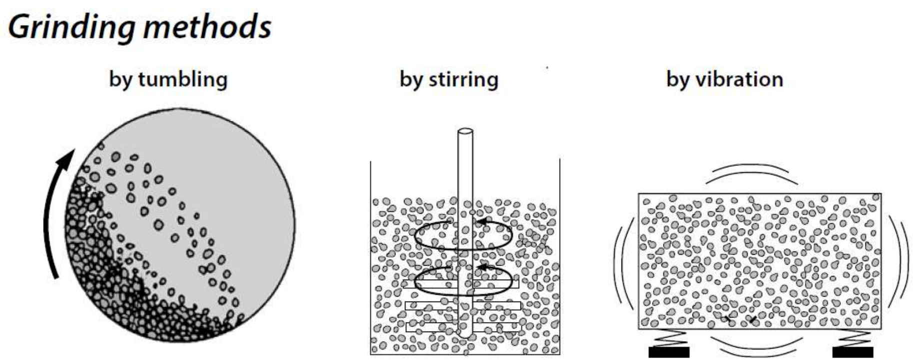
Model	Tire dimensions mm	Max. motor power kW	Max. motor power HP	H mm (inch)	L mm (inch)	W mm (inch)
HRC™1200	1200 x 750	2 x 440 kW	2 x 590 HP	2200 (87)	1610 (639)	4400 (173)
HRC™1450	1450 x 900	2 x 650 kW	2 x 872 HP	3556 (140)	2050 (81)	5196 (205)
HRC™1700	1700 x 1000	2 x 900 kW	2 x 1207 HP	3730 (147)	3690 (145)	6240 (246)
HRC™2000	2000 x 1650	2 x 2300 kW	2 x 3084 HP	5309 (209)	6079 (239)	9512 (375)
HRC™2400	2400 x 1650	2 x 3000 kW	2 x 4023 HP	6646 (262)	3630 (143)	9092 (358)
HRC™2600	2600 x 1750	2 x 3700 kW	2 x 4962 HP	6030 (237)	5660 (223)	9380 (369)
HRC™3000	3000 x 2000	2 x 5700 kW	2 x 7644 HP	6937 (273)	6480 (255)	10800 (425)

Grinding – Introduction

- ❑ Size reduction by crushing has a size limitation for the final products. If we require further reduction, say below 5-20 mm, we have to use the processes of grinding.
- ❑ Grinding is a powdering or pulverizing process using the rock mechanical forces of impaction, compression, shearing and attrition.
- ❑ **The two main purposes for a grinding process are:**

1. To liberate individual minerals trapped in rock crystals (ores) and thereby open up for a subsequent enrichment in the form of separation.
2. To produce fines (or filler) from mineral fractions by increasing the specific surface.

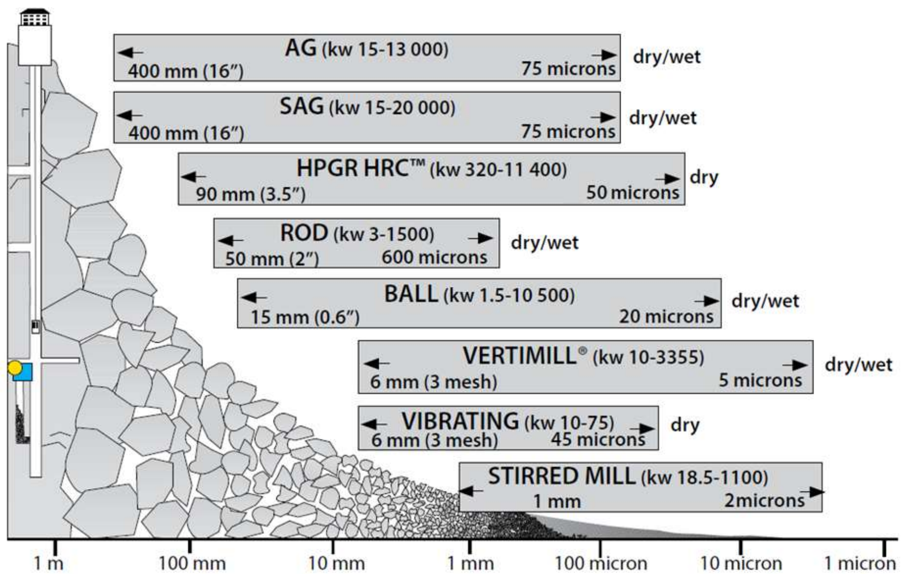
Grinding methods



Grinding mills – Reduction ratios

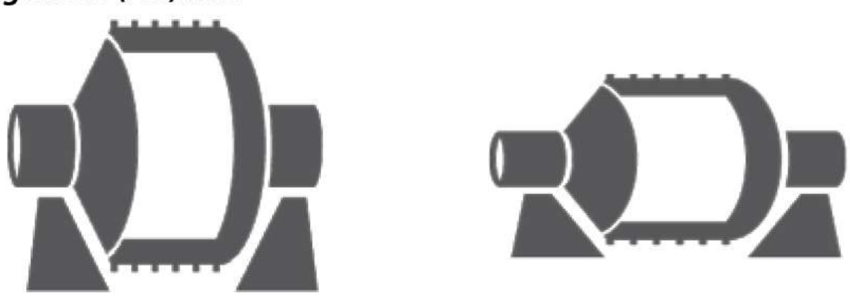
- All crushers including impactors have limited reduction ratios. Due to the design there is a restriction in retention time for the material passing.
- In grinding as it takes place in more "open" space, <u>the retention time is longer and can easily be adjusted during operation</u>.
- Below the theoretical size reduction and power ranges for different grinding mills are shown. In practice also size reduction by grinding is done in optimized stages.

Grinding mills – Reduction ratios



Grinding – Tumbling mills

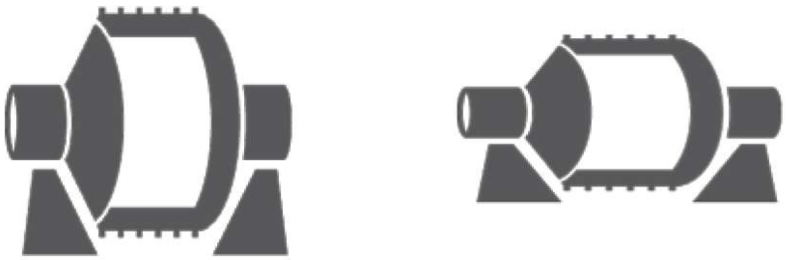
Autogenous (AG) mill



- Wet or dry
- Primary, coarse grinding (up to 400 mm feed size)
- Grinding media is grinding feed
- High capacity (short retention time)
- Sensitive to feed composition (critical size material),

Grinding – Tumbling mills

Semi – Autogenous (SAG) mill



High L/D　　　　Low L/D

- Wet or dry
- Higher capacity than A-G mill grinding
- Primary, coarse grinding (up to 400 mm feed size)
- Grinding media is grinding feed plus 4-18% ball charge (ball dia.100-125 mm)
- High capacity (short retention time)
- Less sensitive to feed composition (critical size material)

Grinding – Tumbling mills

Peripheral = محیطی، پیرامونی

Rod mill

Overflow　　　　End peripheral discharge　　　　Center peripheral discharge

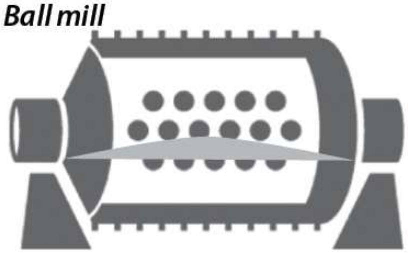
- Wet only
- Coarse grind
- Primary mill at plant capacities of less than 200t/h
- Coarse grinding with top size control without classification
- Narrow particle size distribution

- Mostly dry
- Coarse grind and high capacity
- Special applications
- End discharge: finer product
- Centre discharge: rapid flow, less fines
- Narrow particle distribution

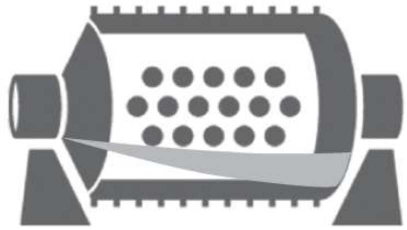
Note! No grate discharge

Grinding – Tumbling mills

Ball mill



Overflow



Grate discharge

- Wet only
- Robust and simple
- Mostly in closed circuit (secondary)
- Finer grind (longer retention time)
- Higher risk for over grinding
- Ball charge 35-40%

Data sheet, see 3:45

- Dry or wet
- Discharge end more complicated
- Mostly in closed circuit (secondary)
- Coarser grind (shorter retention time)
- Lower risk for over grinding
- Can take about 5-10% more ball with correspondingly higher through put

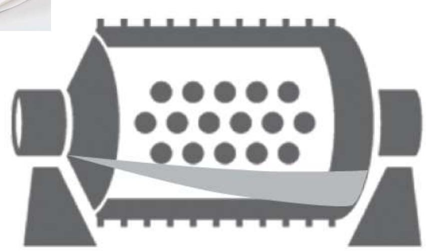
Grinding – Tumbling mills

Porcelain = ظروف چینی

Flint = سنگ چخماق

Pebble mill

- Wet or dry
- Always grate discharge
- Secondary grinding
- Grinding media:
  - A fraction screened out from feed
  - Flint pebbles
  - Porcelain balls
  - Al_2O_3 balls **(alumina)**
- Larger than ball mills at same power draw
- Grinding without metallic contamination

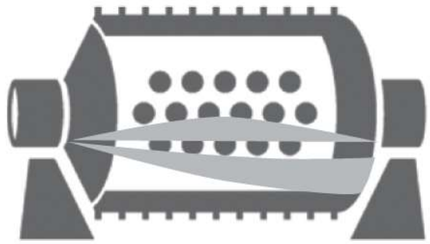


Flint is a hard, sedimentary cryptocrystalline form of the mineral quartz, categorized as a variety of chert.

Grinding – Tumbling mills

Spherical roller antifriction bearing supported mill

- Wet or dry
- Overflow or grate discharge
- Economic solution
- Simple design type trunnion anti-friction roller bearings and lubrication system
- Smaller capacity
- Reliable technology



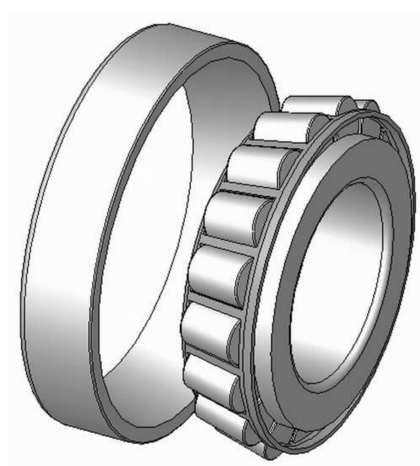
Plain Bearing

Ball Bearing

Roller Bearing

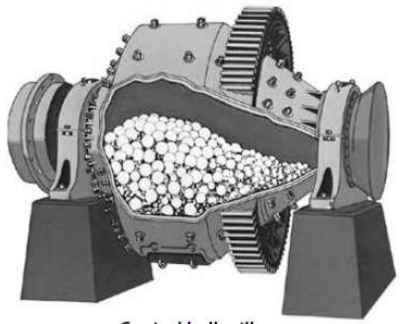
Grinding – Tumbling mills

Ball bearing



roller bearing

Grinding – Tumbling mills



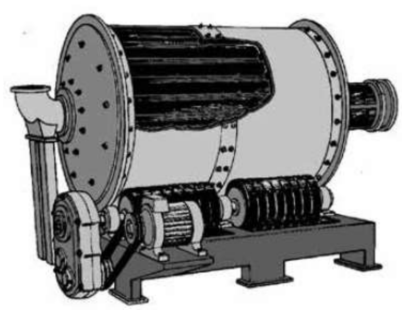
Conical ball mill

- Wet or dry (air swept)
- Overflow or partial grate
- Conical shell for "graded" ball charge
  and optimal size reduction
- Only available in small and inter-mediate sizes
- Efficient "high reduction ratio" grinding

Grinding – Tumbling mills

❑ Special tumbling mills

SRR Mill = Solid Rubber Roller Mill

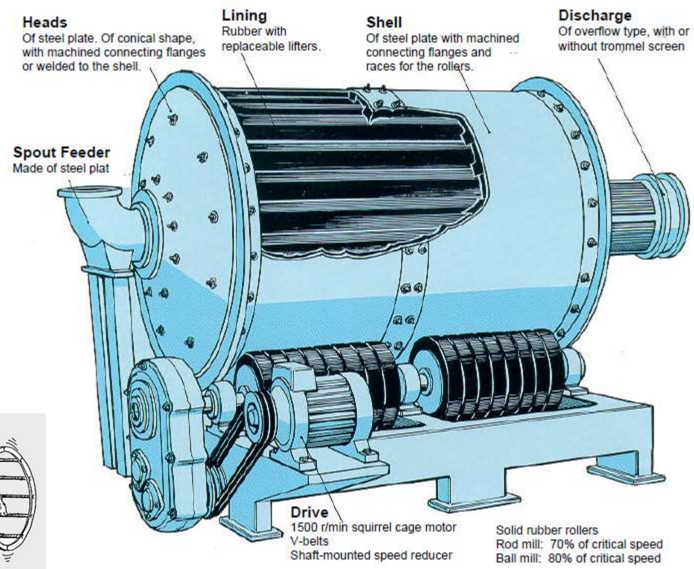


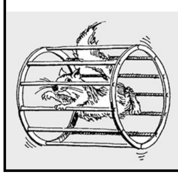
SRR (Rubber roller mill)

- Wet or dry
- Overflow and grate discharge
- Light and fabricated construc-tion
- Ready assembled on steel frame
- Easy to move
- Limited in size (max. dia. 2.4 m)

Grinding – Tumbling mills

Solid Rubber Roller Mill





Grinding – Stirred mills

VERTIMILL®

- Wet grinding only
- Top or bottom feed
- Grinding by attrition/abrasion
- Primary-, regrinding- or lime slaking mill
- Ideal for "precision" grinding on finer products
- Recommended feed top size of <6 mm
- Equipment sizes from 15 to 4500 HP (11 to 3352 kW)
- Ball size max 50mm

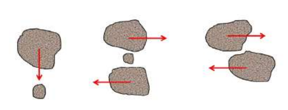


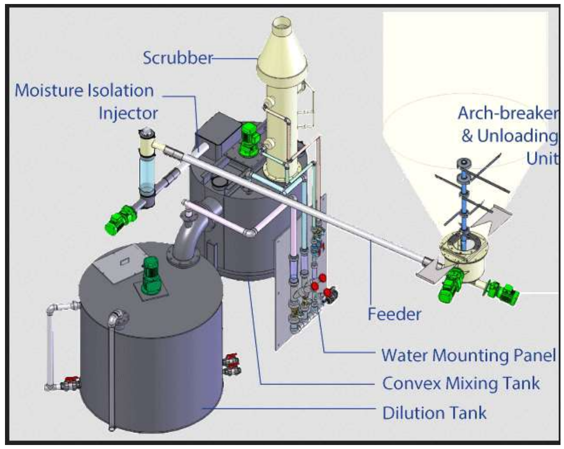
FIGURE 7.1 Mechanisms of breakage: (a) Impact or compression, (b) Chipping or attrition, and (c) Abrasion.

Grinding – Stirred mills

Lime = CaO → slaked lime = $Ca(OH)_2$

Calcium hydroxide (traditionally called slaked lime) is an inorganic compound with the chemical formula $\mathbf{Ca(OH)_2}$

Lime Slaker



VERTIMILL®

- **Comparison with conventional tumbling mills:**
  - Lower installation cost
  - Lower operating costs
  - Higher efficiency
  - Less floor space
  - Simple foundation
  - Less noise
  - Few moving parts
  - Less overgrinding
  - Better operation safety

VERTIMILL®

VERTIMILL®

Grinding – Stirred mills

Stirred Media Detritors (SMD)

Stirred media grinding mlll

Wet grinding only

- Open or closed circuit
- Recommended feed size 100 micron and below
- Product size down to 2 micron

Grinding media:

Ceramic or Sand Grinding Media, 1-8 mm in diameter

Ceramic media is typically recommended because of lower media consumption, higher grinding efficiency, and lower wear rates of internal components.

1 Lab Unit, 2 Pilot Units, and 4 full size machines are available (90 kW, 185 kW, 355 kW,and 1100 kW).

Grinding – Stirred mills

Stirred Media Detritors (SMD)

Stirred Media Detritor
SMD 1100 E

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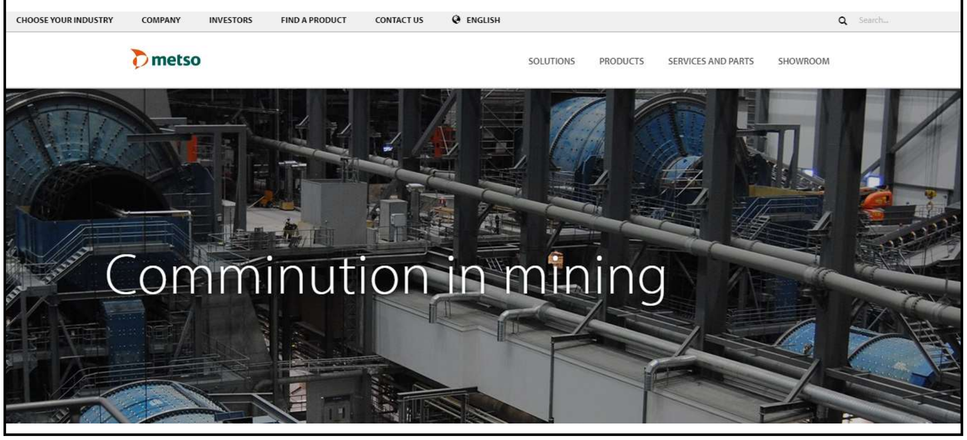
https://www.metso.com/contacts/



Metso

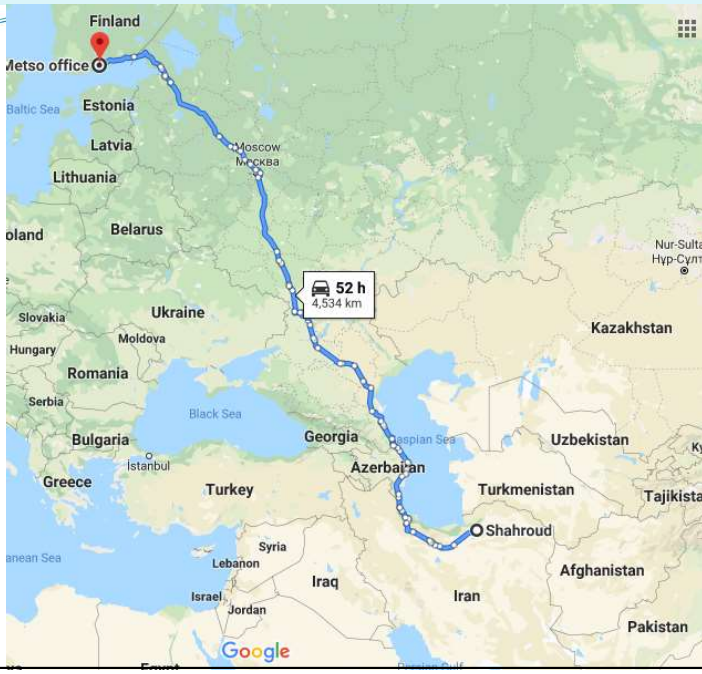
Metso

Metso

https://www.metso.com/industries/mining/comminution/

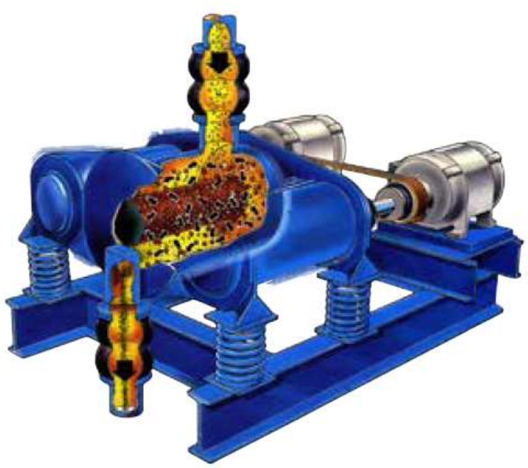
https://www.metso.com/contacts/

Metso



Grinding – Vibrating mills

Vibrating ball mill

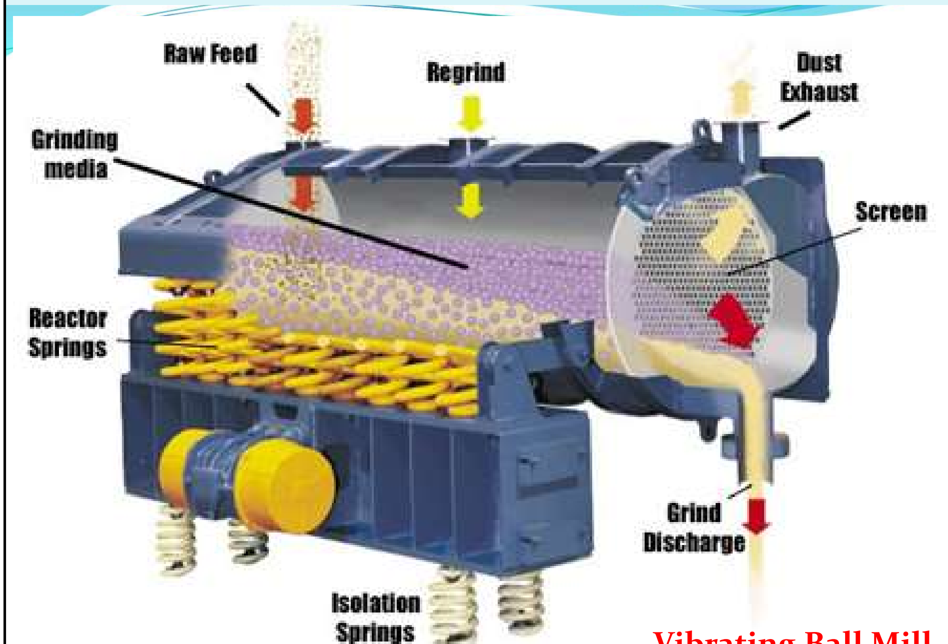


- Wet or dry
- Impact, shearing and attrition
- Open or closed circuit
- Short retention time - less overgrinding
- Feed size, minus 5 mm
- Limited in size
  2x37 kW, 2x50 hp
- High noise level
- Low cost, simple installations
- Low capacity
- Specially applications

Grinding – Vibrating mills

Vibrating Ball Mill

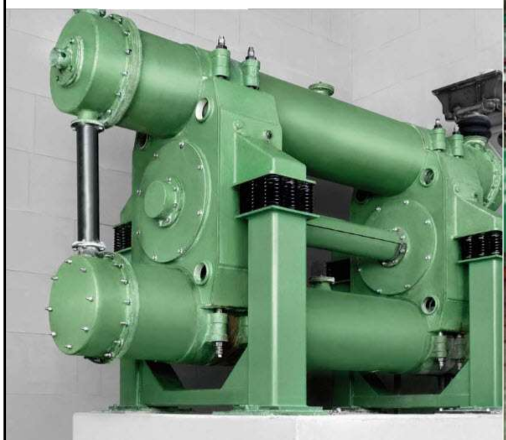
Grinding – Vibrating mills



Vibrating Ball Mill

Grinding – Vibrating mills

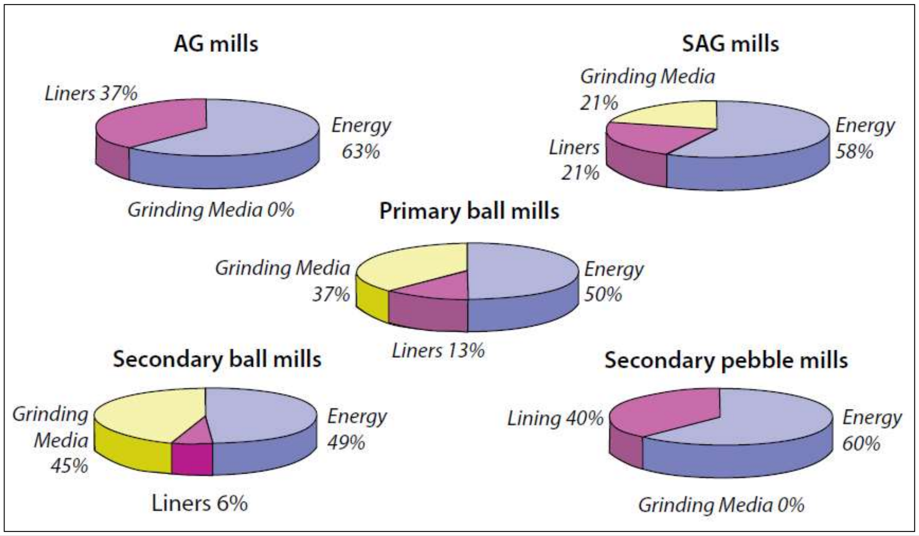
آسیای ارتعاشی دو سیلندری



Grinding – Vibrating mills

Cost of grinding – Typical

- ❑ The main costs for grinding are energy, liners and grinding media. They are different for different mill types. Below some figures for tumbling mills



Mill linings – Basic

- ❑ Use rubber linings wherever possible due to lifetime, low weight, easy to install and noise dampening.
- ❑ When application is getting tougher use steel-capped rubber, still easier to handle than steel.

- ❑ When these both options are overruled (by temperature, feed size or chemicals) use steel.
- ❑ Ore-bed is a lining with rubber covered permanent magnets used for special applications like lining of Vertimills, grinding of magnetite a.o. (All The Other)

Lining components

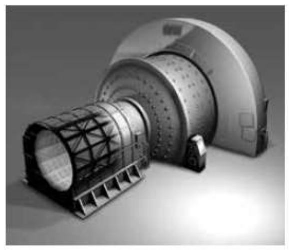
Rubber linings

Poly-Met® linings

Metallic linings

Orebed® linings

Trommel screens



Discharge systems

Grinding mills – Sizing

- ❑ Fundamental to all mill sizing is determining the necessary specific power consumption for the grinding stage (primary, secondary, tertiary etc.) in question.
- ❑ It can be established in many ways, some including:
  1. Operating data from existing mill circuit (direct proportioning).
  2. Grinding tests in pilot scale, where the specific power consumption is determined (kWh/t dry solids).
  3. Laboratory tests in small batch mills to determine the specific energy consumption.
  4. Energy and power calculations based on Grindability Index, for example, Bond work index (called Wi and normally expressed in kWh/short ton).
  5. Population balance modeling and other simulation techniques

Grinding mills – Sizing

- Scale-up criterion is the **net specific power consumption**, i.e. the power consumed by the mill rotor itself minus all mechanical and electrical losses divided by the feed rate of solids.
- For the full scale mill this is then to be multiplied by the feed rate to get the **net mill power**.
- This must then be increased by the anticipated **mechanical inefficiencies** (trunnion and pinion bearing friction, ring gear/pinion friction and possible speed reducer losses) as well as electrical losses, in order to arrive at the **gross power**.

ring gear :چرخ دنده

Grinding mills – Sizing

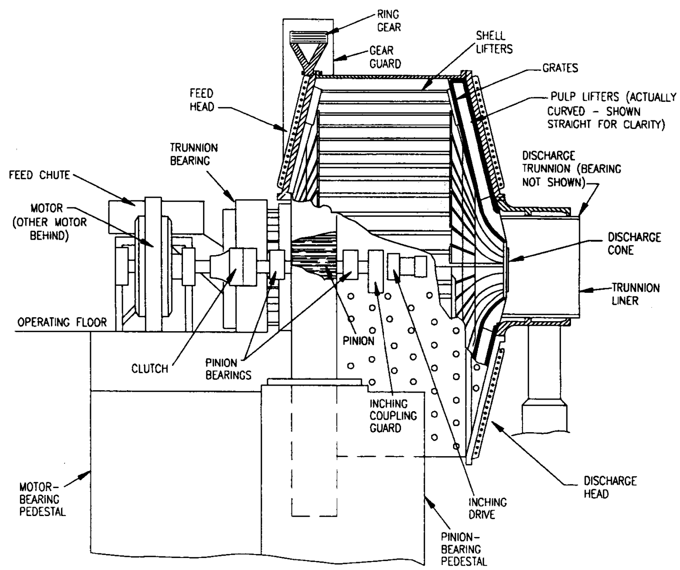
ring gear

trunnion bearing

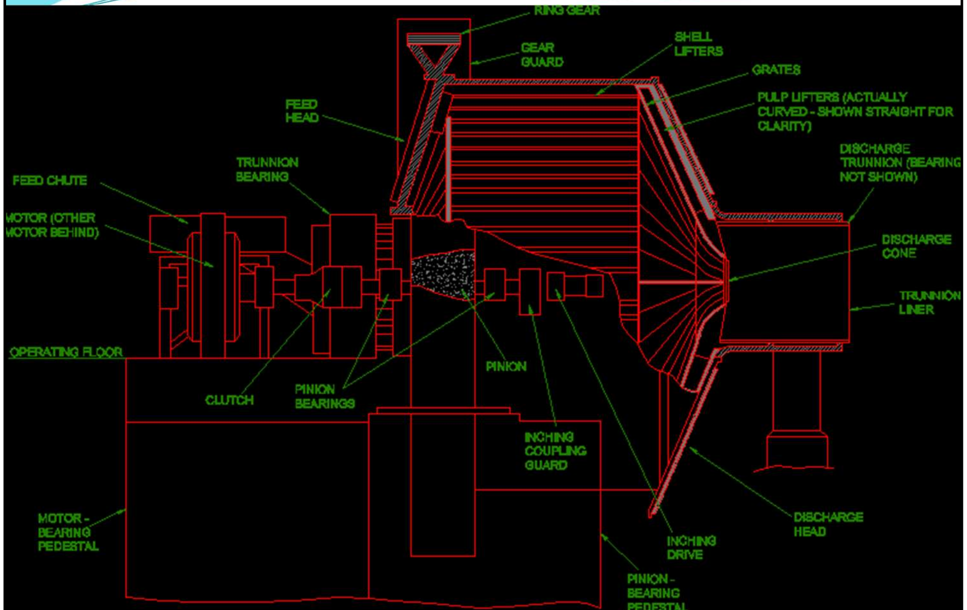
Grinding mills – Sizing

pinion bearing

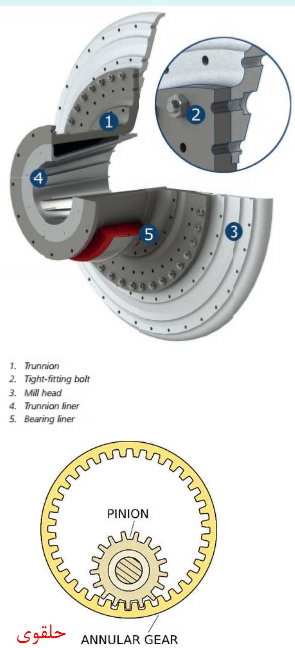
Grinding mills – Sizing

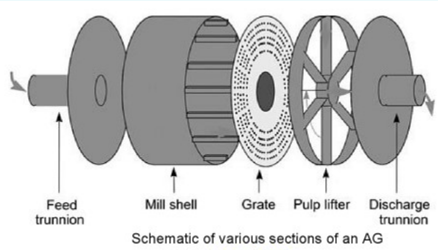


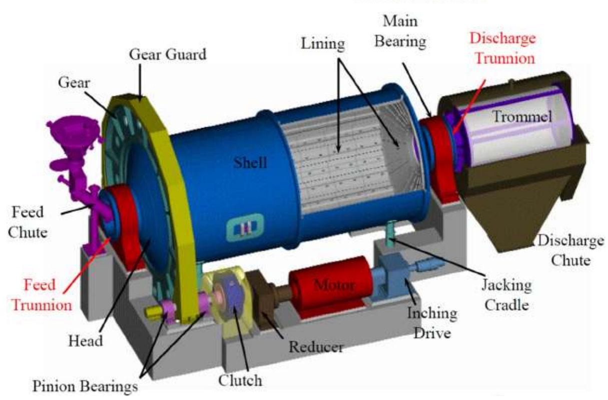
Grinding mills – Sizing



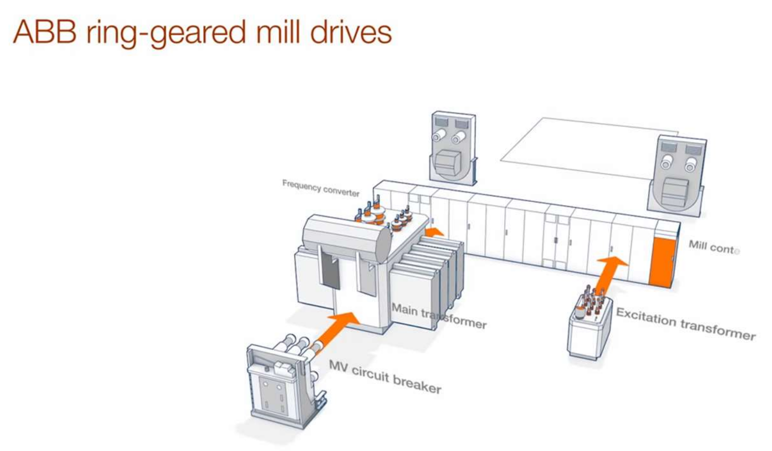
Grinding mills – Sizing







Grinding mills – Sizing

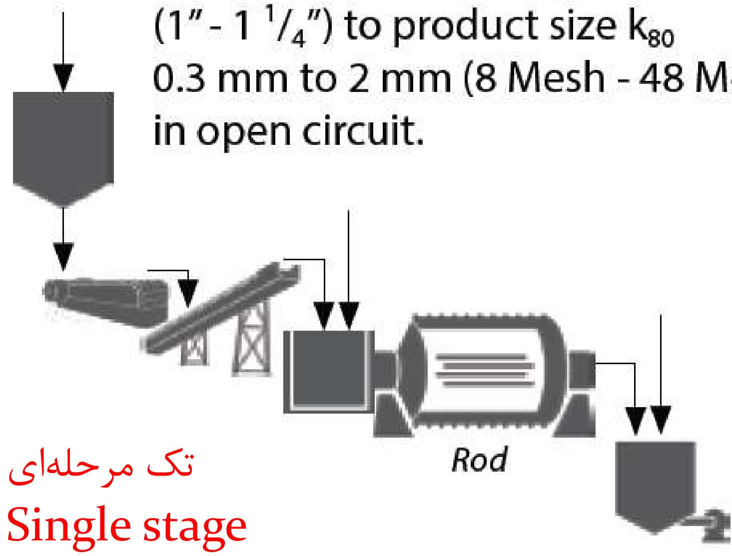


Grinding mills – Sizing

- In our labs we can run tests batchwise (in kg scale), or for more critical applications in pilot scale (200-1000 kg/h). <u>The pilot tests are more accurate, but also more expensive</u>.
- <u>**For all AG or SAG installations such tests are mandatory**, since they will tell whether this type of grinding is possible at all, as well as establishing the necessary specific power consumption.</u>

Grinding circuits

Wet grinding of feed k_{80} 25 - 30 mm (1″ - 1 $^1/_4$″) to product size k_{80} 0.3 mm to 2 mm (8 Mesh - 48 Mesh) in open circuit.



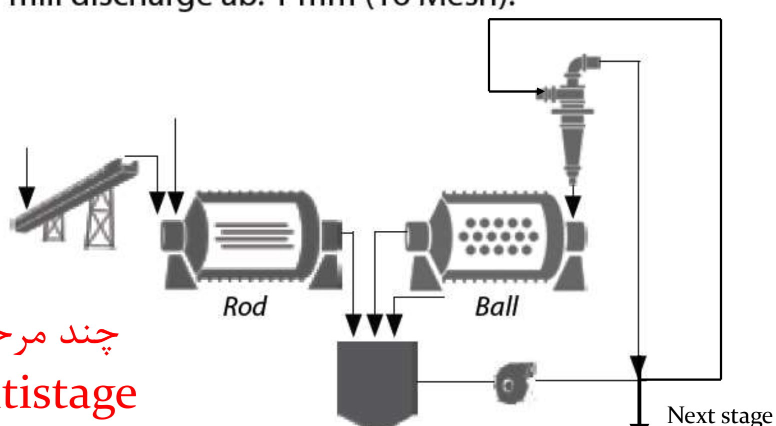
تک مرحله‌ای

Single stage

Grinding circuits

One of the most common flow-sheets for concentrating plants to wet grind - 25 mm (1″) feeds (or finer) to desired product size. Rod mill discharge ab. 1 mm (16 Mesh).

ab. = about

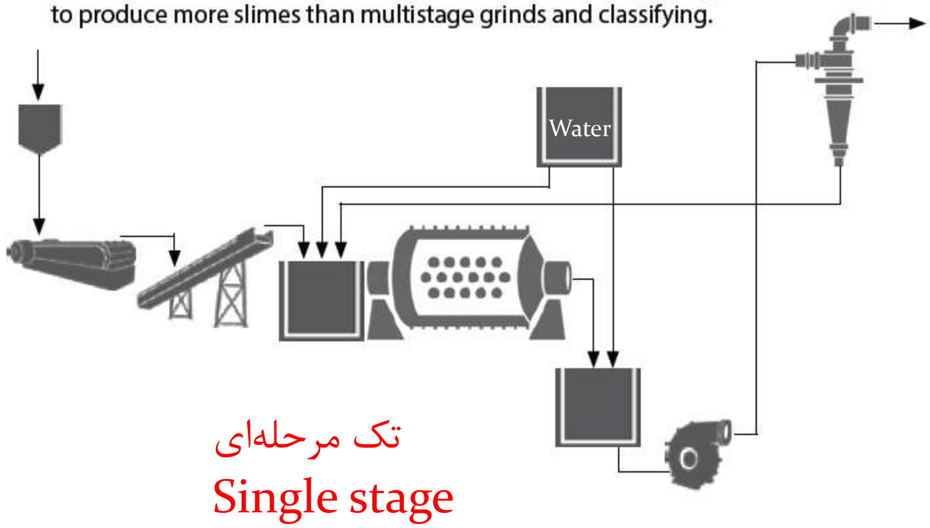


چند مرحله‌ای

Multistage

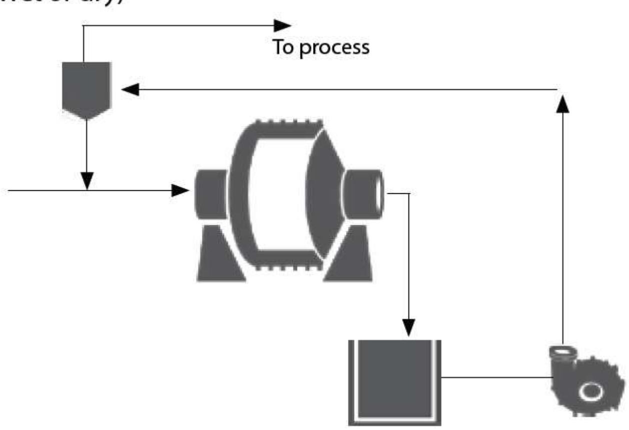
Typical duties: (Single stage ball grinding and single classification circuit)

The most simple and common (although not the most efficient) circuit to wet grind from max. feed sizes of k80 15 mm (5/8″) and finer to required product sizes. Tend to produce more slimes than multistage grinds and classifying.



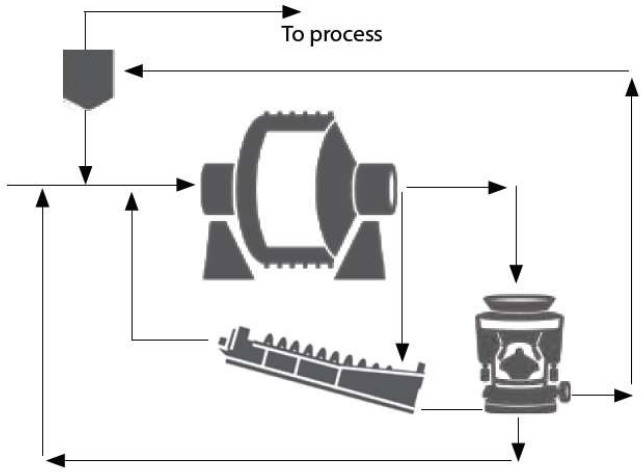
Typical duties: 1. Autogenous-Single stage

For the rare cases where primary AG milling will inherently produce the required product size. (Wet or dry)

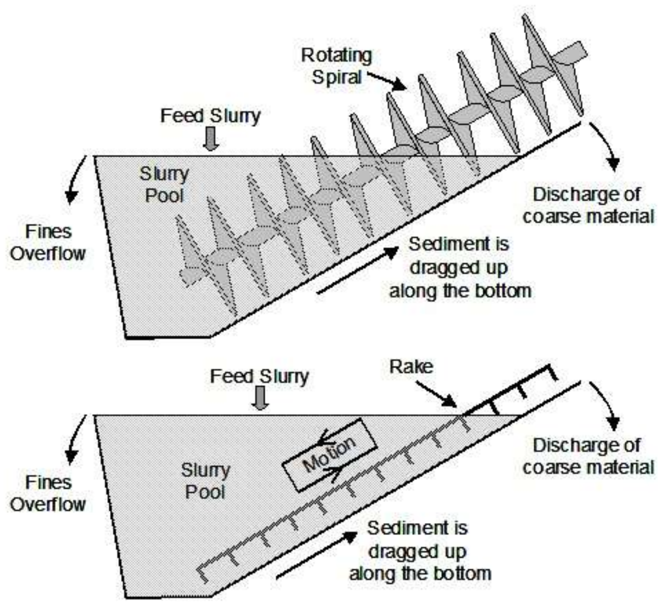


Typical duties: 2. Autogenous + Crusher

- For the also not too common cases where **critical size** pebbles are created and thus inefficient grinding results.
- With pebble ports in the mill grate and separate crushing of the critical sizes this can be remedied. However, resulting product size must match product requirements. (Wet or dry)

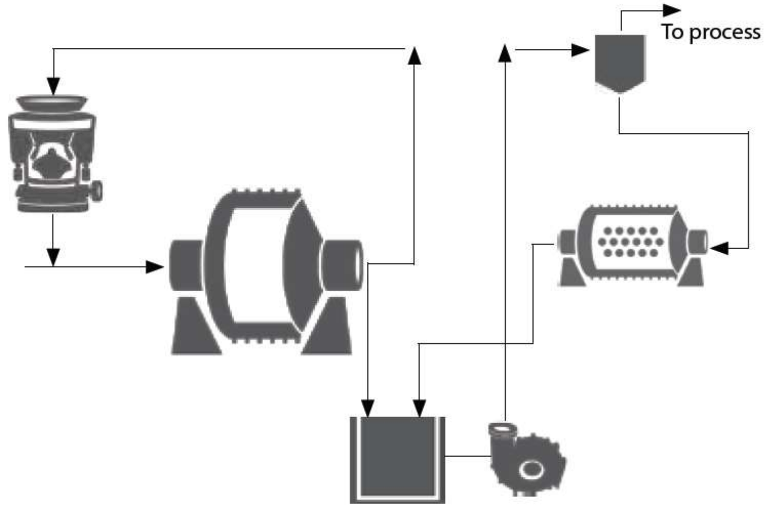


Typical duties: 2. Autogenous + Crusher



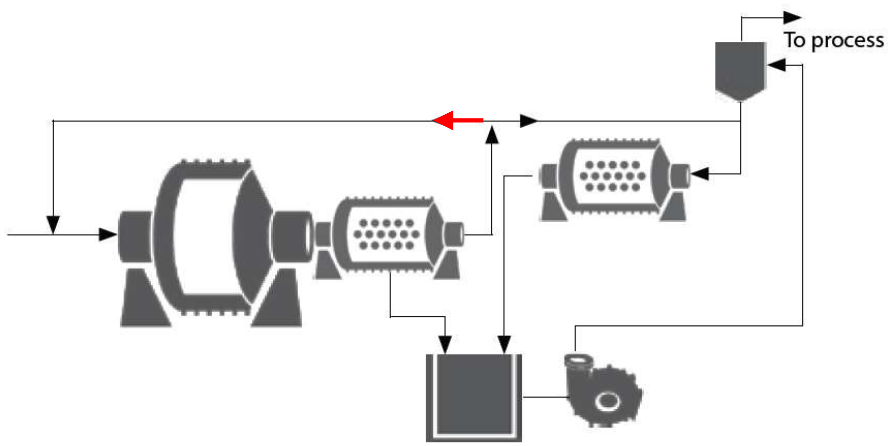
Typical duties: 3. Autogenous + Ball mill + Crusher

- This is also called "**ABC-circuit**" and has a ball mill added in comparison with the above circuit No 2. This can be used to correct a too coarse product from the primary mill, and in this way be more useful and common. Mostly operated wet, but also dry possible.



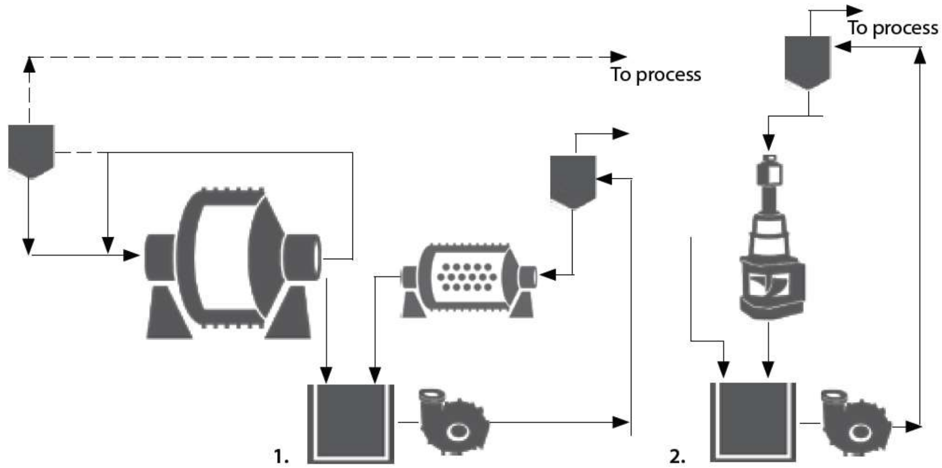
Typical duties: 4. Autogenous + Pebble mill

- Two stage AG-grinding with the primary mill in open circuit and the secondary pebble mill in closed circuit.
- The pebble mill gets competent pebbles screened out from the primary mill discharge as needed (or otherwise recirculated to the primary mill). Frequently used by the Boliden mines (Sweden).



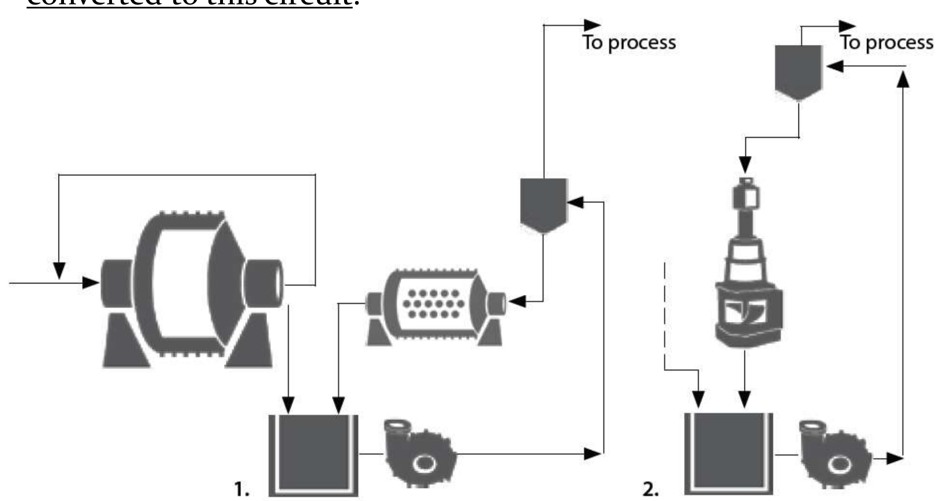
Typical duties: 5. Autogenous + Ball mill / VertiMill

- Same as the above, but with the pebble mill replaced by a ball mill or a Vertimill. <u>This is used when there is not enough pebbles available in the circuit, or all autogenous grinding produces too much fines</u>.



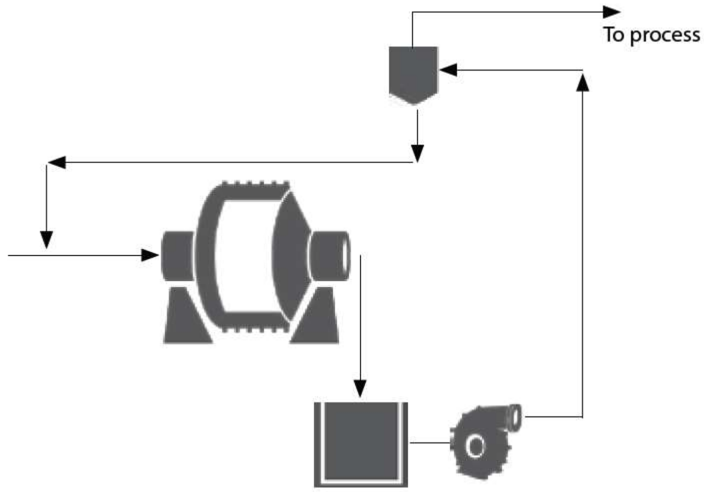
Typical duties: 6. Semi-autogenous + Ball mill / VertiMill

- Same as the above No. 5, but with the primary mill as semi-autogenous, which in most cases means <u>higher capacity</u> for the circuit. <u>Many circuits type No. 5 in the US /Canada have been converted to this circuit</u>.



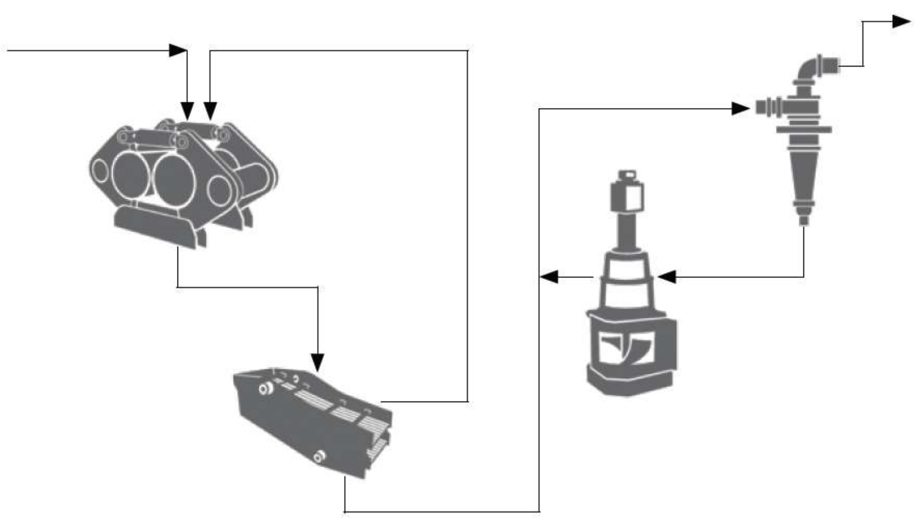
Typical duties: 7. Semi-autogenous-Single stage

- Same as No.1 above, but with the mill as semi-autogenous. <u>This will increase capacity as well as application range, but will also increase wear costs</u> (balls and lining) and still be dependent on “natural” product size being close to the desired. Common circuit in the US and Canada.



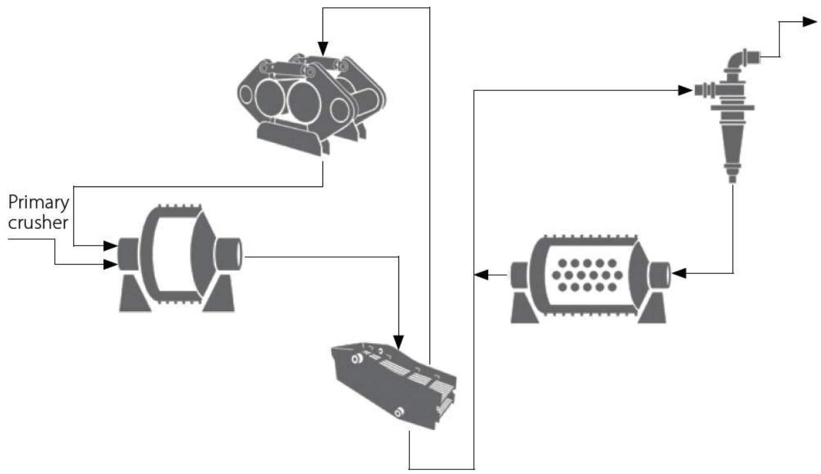
Typical duties: 8. HRC™ + Vertimill®

- In this circuit, the cone crusher product is fed to the HRC™ which produces the required reduction for enrichment with the Vertimill processing as the regrind. <u>When applicable, this type of circuit can offer significant energy savings</u>.



Typical duties: 9. AG mill + HRC™ + Ball mill

- In this circuit, the AG mill is followed by a single deck screen with the oversize being recirculated through the HRC™ before returning to the AG mill. The undersize from the screen is fed to the ball mill circuit sump. The AG mill can be replaced by a SAG Mill, however special care should be used to **detect and remove balls from the HRC™ feed**.

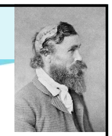


VERTIMILL® Circuits

- Typical duties: 10. Reversed closed circuit

- Typical duties: 11. Direct feed

Typical duties: 10. Reversed closed circuit



- **Scalped or fresh feed directly into the mill**
- If it is desirable to use cyclones, the next decision is where in the process the cyclones should be – either closed circuit or reversed closed circuit.
- Typical closed circuit has the feed to the Vertimill circuit coming directly to the mill. This means that every particle regardless of size will enter the mill and may be ground.
- For reverse close circuit, the feed to the Vertimill circuit is introduced at the cyclone sump.

Typical duties: 10. Reversed closed circuit

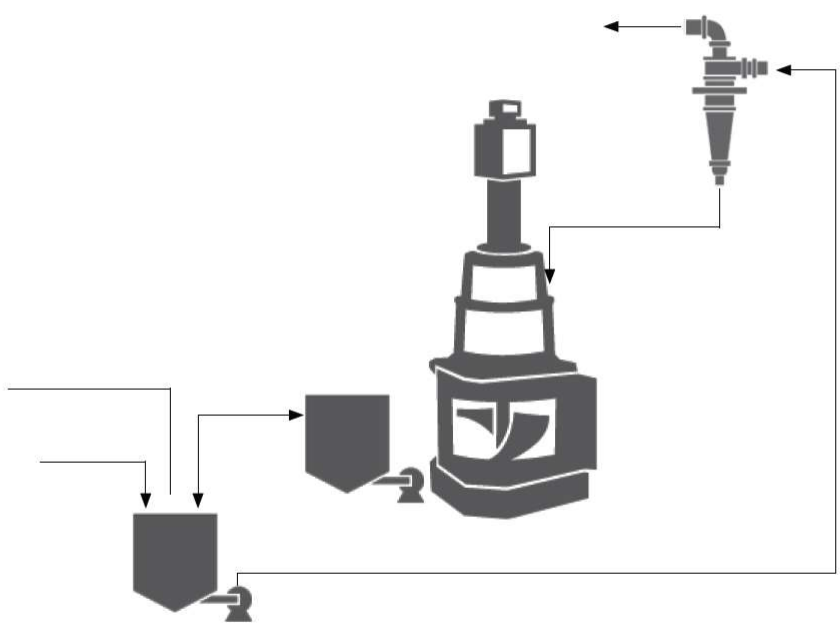
- The material feeding the circuit that is already at product size will have a chance to bypass the Vertimill all together, and **the grinding energy will only be spent on the coarse material**.
- This can reduce the size (and capital cost) of the Vertimill installation.
- Mineralogically, there may be some benefit to direct feed in that **flotation recovery may improve** if all the particles surfaces, regardless of the particle size, are polished or refreshed.
- The reversed arrangement will **minimize fines generation**, which may also **improve recovery**.
- To best make a mineralogical decision, you need to have a good understand on where the losses are in the flotation circuit.

Typical duties: 10. Reversed closed circuit

- From a circuit energy perspective, in general, if the feed has very little material (<10%) that is final product size, it is better to feed it directly to the mill because the cyclone or other classifying device will send it all back to the Vertimill anyway and you would be putting undue load on the cyclone feed pumps.
- If there is a fair amount of fines and the classification is reasonably efficient, pre-classifying the material is beneficial.

undue= بی مورد، غیر ضروری

Typical duties: 10. Reversed closed circuit



Typical duties: 11. Direct feed

❑ **Circuit Configuration**

❑ In addition to cyclones or other external classification, there are four ways to configure a Vertimill circuit:

- Top feed with recycle system
- Top feed without recycle system
- Bottom feed with recycle system
- Bottom feed without recycle system

❑ **Bottom feed advantages**

- All Particles must pass through the media, every particle surface is refreshed
- Provides additional upward classifying flow
- Can help free (v.) locked or frozen charge at start up
- Potentially more efficient because of lack of short circuiting
- need no return valves or a tall tank

Typical duties: 11. Direct feed

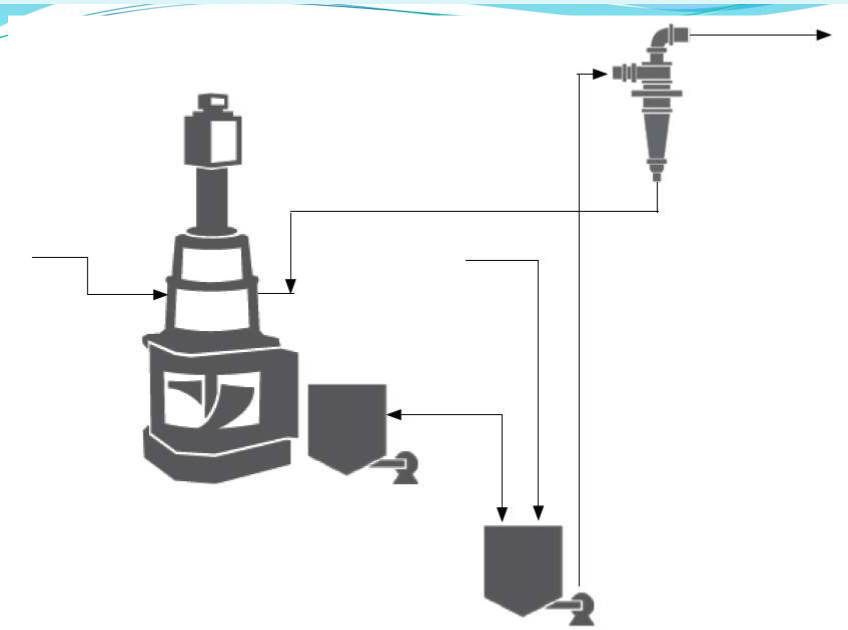
❑ **Bottom feed disadvantages**

- Cannot be bottom fed via gravity and requires a feed pump
- Back flow
- Fine particles must pass through the media – potential for over grinding
- Piping must loop above ball charge height so ball to not get to the pump
- Requires variable speed pumps
- Tank requires flow split and level control
- Minimum inlet pressure requirement to prevent plugging

❑ **Top feed advantages**

- Does not require a feed pump; can be feed directly from cyclones
- No inlet pressure requirement

Typical duties: 11. Direct feed



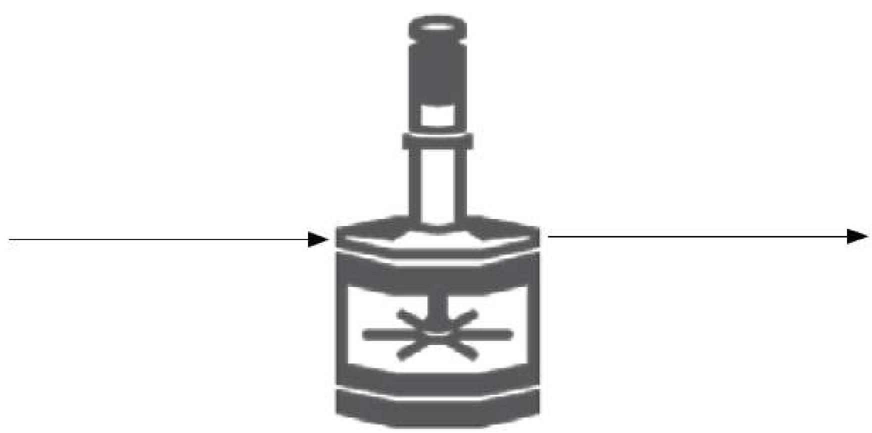
Stirred Media Detritors (SMD) Circuits

- Typical duties: 12. Open circuit, whole feed
- Typical duties: 13. Open circuit, scalped feed
- Typical duties: 14. Closed circuit

Typical duties: 12. Open circuit, whole feed

- ❑ SMDs already <u>utilize inert grinding media</u> to improve flotation recovery, but the surface preparation of the particle may also be important for the flotation response. inert: ساكن
- ❑ <u>The whole stream can be fed direct to the mills in open circuit</u> so that all of the material gets some grinding <u>to prepare the surface for flotation</u>.
- ❑ <u>If the upstream process can provide steady feed rate and solids concentration (i.e. a thickener), the SMD can be operated in open circuit with no additional equipment required.</u> buffer: حائل
- ❑ If the feed rate or solids concentration will <u>fluctuate periodically</u>, then including a <u>buffer tank</u> to feed the mills is advised.

Typical duties: 12. Open circuit, whole feed

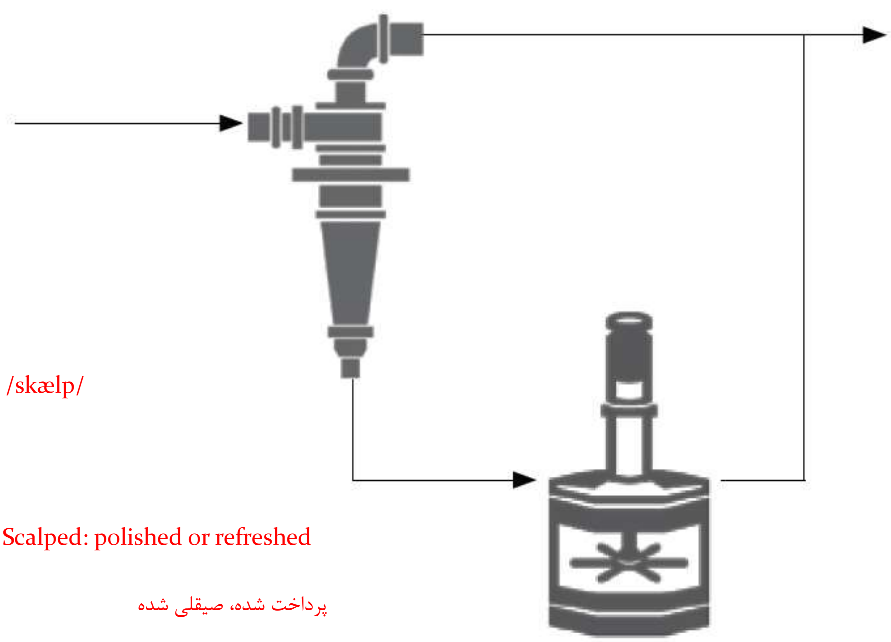


Typical duties: 13. Open circuit, scalped feed

- If the losses in the flotation circuit are in the coarse, un-liberated material and fines generation needs to be minimized, then the SMD will be more efficient at increasing the recovery by grinding just the coarse material.
- Scalping cyclones can be used ahead of the mill to scalp the fines and send them straight to the next process, and the cyclone underflow feeds the SMD, and is then recombined with the cyclone overflow for the next process.
- As previously stated, the SMD is best operated between 40-50% solids, and a scalping cyclone also provides a nice solution to thicken the feed to the mill.

Scalping = جداکننده

Typical duties: 13. Open circuit, scalped feed



/skælp/

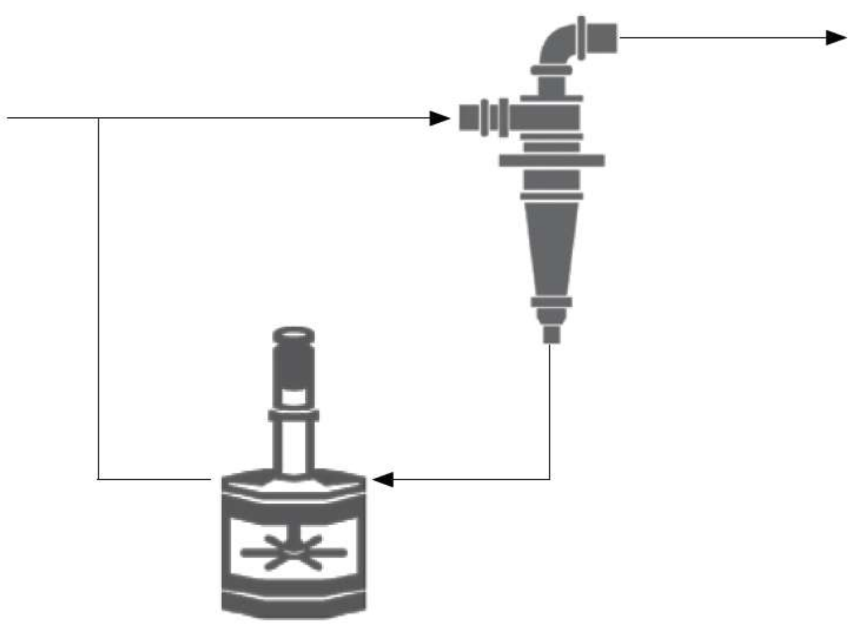
Scalped: polished or refreshed

پرداخت شده، صیقلی شده

Typical duties: 14. Closed circuit

- The SMD can also be operated in closed circuit. This arrangement provides all the advantages of the Open Circuit, Scalped feed configuration, but also provides a method to control the particle size other than feed rate and mill power. Other than = غير از
- The SMD operates quite well in an open circuit configurations, and only a handful are operated in closed circuit.
- For ultrafine grinding, operating in closed circuit is difficult because the small diameter cyclone can easily plug.
- Closed circuit configuration is primarily used in coarser grinding applications and when the specific energy is low - the average residence time of the particle is short.

Typical duties: 14. Closed circuit



Metso Mining and Construction

Brand names in rock and minerals processing

- Allis Chalmers (AC)
- Allis Minerals System
- Altairac
- Armstrong Holland
- Barmac
- Bergeaud
- Boliden Allis
- Cable Belt
- Conrad Scholtz
- Denver
- Dominion
- FACO
- GFA
- Hardinge
- Hewitt Robins
- Kennedy Van Saun KVS
- Kue-ken Seco
- Koppers
- Lennings
- Lokomo
- Marcy
- Masterscreens
- McDowell Wellman
- McNally Wellman
- Neims
- NICO
- Nokia
- Nolan
- Nordberg
- MPSI
- Orion
- PECO
- Pyrotherm
- Read
- REDLER
- Sala
- Scamp
- Skega
- Stansteel
- Stephens – Adamson
- Strachan & Henshaw
- Svedala
- Thomas
- Tidco
- Trellex
- Tyler

Allis-Chalmers

Allis-Chalmers

ALLIS-CHALMERS

Industry	industrial machinery, grain-milling machinery, power plant equipment, mining equipment, agricultural machinery, heavy equipment (construction)
Successor	AGCO, Allis-Chalmers Energy
Founded	Milwaukee, Wisconsin (1901)
Headquarters	U.S. based, global exports
Products	generators, engine-generators, tractors, threshers, combines, farm implements, bulldozers, milling machinery, others

Grinding – Power calculation

The most common formula for this is the Bond* formula

W (specific power consumption) = 10 x Wi ($\frac{1}{\sqrt{P}} - \frac{1}{\sqrt{F}}$)

with P and F the 80% passing sizes of product and feed in microns and Wi expressed as kWh/sh.t.

Then for P = 100 and F very large, Wi is roughly the same as W, or in other words equal to the specific power consumption to comminute a material from infinite size to k_{80} = 100 microns see below.

* Fred Bond, Allis Chalmers Corp.

Mass

1 US ton = 0.907185 Tonne

Grinding – Bonds Work Index*

- *These values are not constant and must be used accordingly!

Solids [kWh/sh.ton]	Wi
Andesite	18.25
Barite	4.73
Basalt	17.10
Bauxite	8.78
Cement clinker	13.45
Cement raw material	10.51
Clay	6.30
Coal	13.00
Coke	15.13
Copper ore	12.72
Diorite	20.90
Dolomite	11.27
Emery	56.70
Feldspar	10.80
Ferro-chrome	7.64
Ferro-manganese	8.30
Ferro-silicon	10.01
Flint	26.16
Fluorspar	8.91
Gabbro	18.45
Glass	12.31
Gneiss	20.13
Gold ore	14.93
Granite	15.13
Graphite	43.56
Gravel	16.06
Gypsum rock	6.73
Hematite	12.84

Solids [kWh/sh.ton]	Wi
Magnetite	9.97
Taconite	14.61
Lead ore	11.90
Lead-zinc ore	10.93
Limestone	12.74
Manganese ore	12.20
Magnesite	11.13
Molybdenum	12.80
Nickel ore	13.65
Oil shale	15.84
Phosphate rock	9.92
Potash ore	8.05
Pyrite ore	8.93
Pyrrhotite ore	9.57
Quartzite	9.58
Quartz	13.57
Rutile ore	12.68
Shale	15.87
Silica sand	14.10
Silicon carbide	25.87
Slag	10.24
Slate	14.30
Sodium silicate	13.40
Spodumene ore	10.37
Syenite	13.13
Tin ore	10.90
Titanium ore	12.33
Trap rock	19.32
Zinc ore	11.56

VERTIMILL® – More than a grinding mill

- The VERTIMILL® grinding mill is considered to be an "intelligent" grinding concept giving an energy saving and controlled process of size reduction for comparison with tumbling mills.

VERTIMILL® – More than a grinding mill

Mineral applications

- Fine / Ultra fine grinding
- Primary grinding
- Secondary grinding
- Tertiary grinding
- "In circuit" regrinding of concentrates

FGD applications

- Fine grinding of lime stone
- Lime slaking, see next page

Fuel preparation

- Clean coal
- Coal / water
- Coal / oil

Flue-gas desulfurization (FGD) is a set of technologies used to remove sulfur dioxide (SO_2) from exhaust flue gases of fossil-fuel power plants, and from the emissions of other sulfur oxide emitting processes.

flue-gas: گاز دودکش، گاز سوخته، گاز مجرای کوره

Vertimill ® as lime slaker

- The Vertimill ® is an excellent lime slaker producing an optimal product in a simple one-step operation.

Typical operation conditions:

Material	Pebble lime with approximately 5 % grit
Feed size	minus 25mm (1")
Product size	80% passing 75 microns to 90-95% passing 45 microns
Percent solids (product)	20-26%
Temperature inside mill (product)	50-82 °C (130-180°F)

slake /sleɪk/: شکفتن، هیدراته کردن
Slaked lime: آهک هیدراته، آهک شکفته

grit: سنگ‌ریزه، شن، ریگ، ماسه‌سنگ

Steel Shot VS Steel Grit

SHOT

SAE No.	S-780	S-660	S-550	S-460	S-390	S-330
Size (mm)	2.4	2.0	1.7	1.4	1.2	1.0

SAE No.	S-280	S-230	S-170	S-110	S-70	
Size (mm)	0.8	0.7	0.6	0.4	0.3	

GRIT

SAE No.	G-10	G-12	G-14	G-16	G-18	G-25
Size (mm)	2.4	2.0	1.7	1.4	1.2	1.0

SAE No.	G-40	G-50	G-80	G-120	
Size (mm)	0.7	0.5	0.3	0.2	

grit: سنگ‌ریزه، شن، ریگ، ماسه‌سنگ

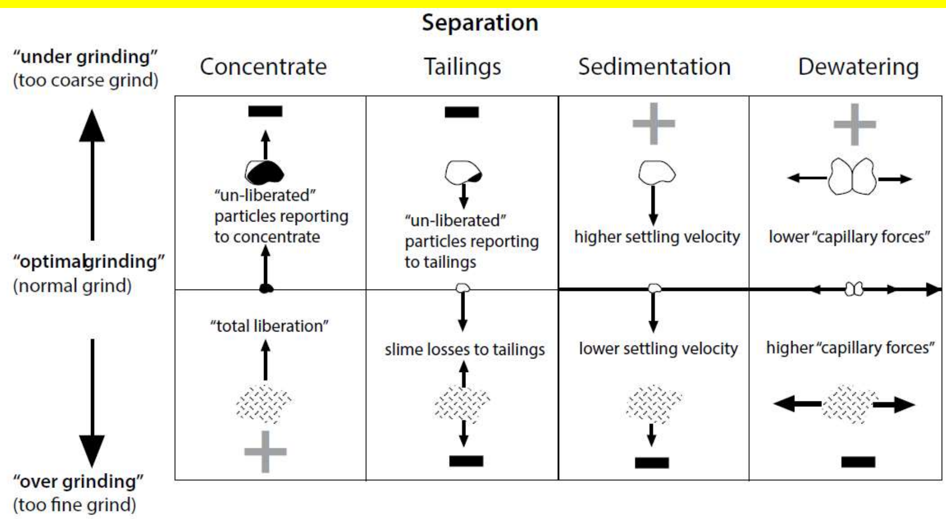
Vertimill ® as lime slaker

Capacities vs mill sizes

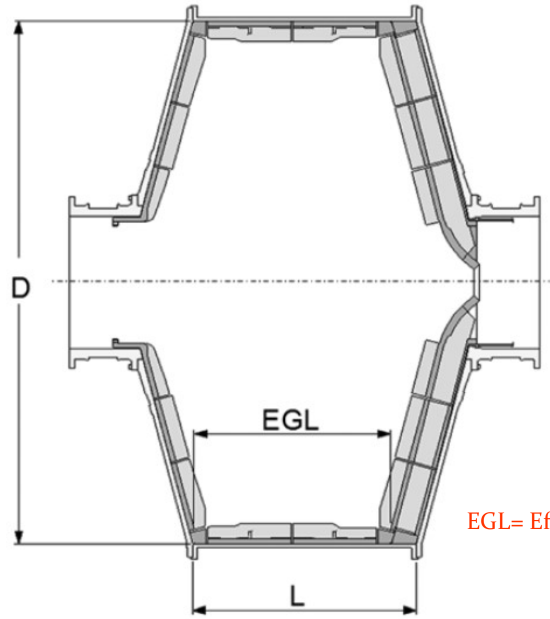
Mtph CaO	Stph CaO	Mill unit	Motor kW	Motorhp
1.4	1.5	VTM-10-LS	7.5	10
2.7	3.0	VTM-20-LS	14.9	20
3.7	4.1	VTM-30-LS	22.4	30
5.3	5.8	VTM-50-LS	37.3	50
6.6	7.3	VTM-100-LS	44.7	60
12.0	13.2	VTM-150-LS	74.6	100
13.9	15.3	VTM-200-LS	111.9	150
18.7	20.6	VTM-300-LS	149.1	200
30.0	33.0	VTM-400-LS	223.7	300

Grinding vs enrichment and upgrading

- In the size reduction stages of grinding we are also creating the conditions for the following process stages of enrichment and upgrading.



AG and SAG mills

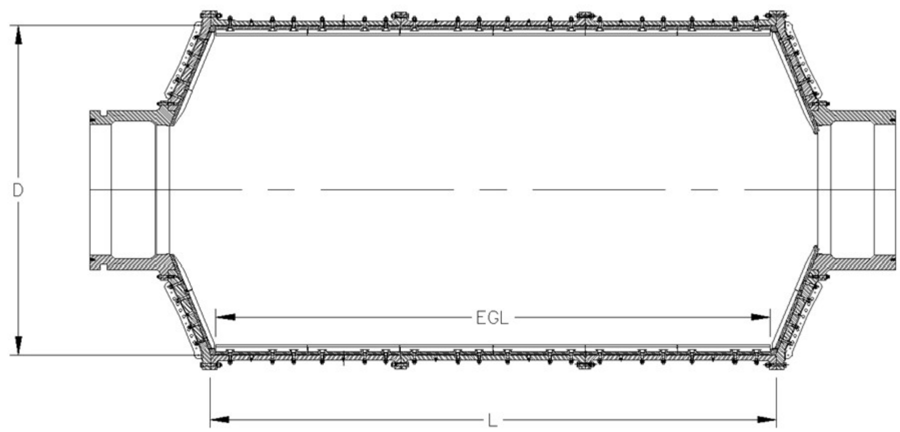


EGL= Effective Grinding Length

AG and SAG mills

Standard Mill size (m)	EGL (m)	Geared/Gearless	Std %TCS	Motor hp/kW (Typical)
12′ x 5′ (3,7 x 1,5)	4′ (1,2)	Geared	75	150-250/110-185
14′ x 6′ (4,2 x 1,8)	5′ (1,5)	Geared	75	300-500/220-370
16′ x 7′ (4,8 x 2,1)	6′ (1,8)	Geared	75	550-850/400-630
18′ x 8′ (5,5 x 2,4)	6.75′ (2,0)	Geared	75	900-1300/670-970
20′ x 8′ (6,0 x 2,4)	6.75′ (2,0)	Geared	75	1000-1750/745-1300
21′ x 10′ (6,4 x 3,0)	8.75′ (2,7)	Geared	75	1600-2500/1200-1860
22′ x 10′ (6,7 x 3,0)	8.75′ (2,7)	Geared	75	2000-3000/1490-2240
24′ x 10′ (7,3 x 3,0)	8.75′ (2,7)	Geared	75	2500-3500/1860-2610
26′ x 10′ (7,9 x 3,0)	8.75′ (2,7)	Geared	75	3000-4500/2240-3350
28′ x 10′ (8,5 x 3,0)	8.5′ (2,6)	Geared	75	3500-5500/2610-4100
28′ x 14′ (8,5 x 4,3)	12.5′ (3,8)	Geared	75	5000-8000/3730-5960
30′ x 12′ (9,1 x 3,7)	10.5′ (3,2)	Geared	75	5000-8000/3730-5960
32′ x 14′ (9,8 x 4,3)	12.5′ (3,8)	Geared	75	7-11000/5-8200
32′ x 16′ (9,8 x 4,8)	14.5′ (4,4)	Geared	75	8-12000/6-8950
34′ x 15′ (10,3 x 4,6)	13.25′ (4,0)	Geared	75	8-13000/6-9700
34′ x 17′ (10,3 x 5,2)	15.25′ (4,6)	Geared	75	10-15000/7-11190
34′ x 19′ (10,3 x 5,8)	17.25′ (5,3)	Geared	75	11-17000/8-12680
36′ x 15′ (11,0 x 4,6)	13.25′ (4,0)	Geared/Gearless	Variable	10-16000/7-11930
36′ x 17′ (11,0 x 5,2)	15.25′ (4,6)	Geared/Gearless	Variable	11-18000/8-13420
36′ x 19′ (11,0 x 5,8)	17.25′ (5,3)	Geared/Gearless	Variable	12-20000/9-14900
38′ x 20′ (11,6 x 6,0)	18′ (5,5)	Geared/Gearless	Variable	15-24000/11-17800
40′ x 22′ (12,0 x 6,7)	19.5′-20′ (5,9-6,1)	Gearless	Variable	19-30000/14-22370
42′ x 25′ (12,8 x 7,6)	22.5′ (6,8)	Gearless	Variable	23-36000/17-26850

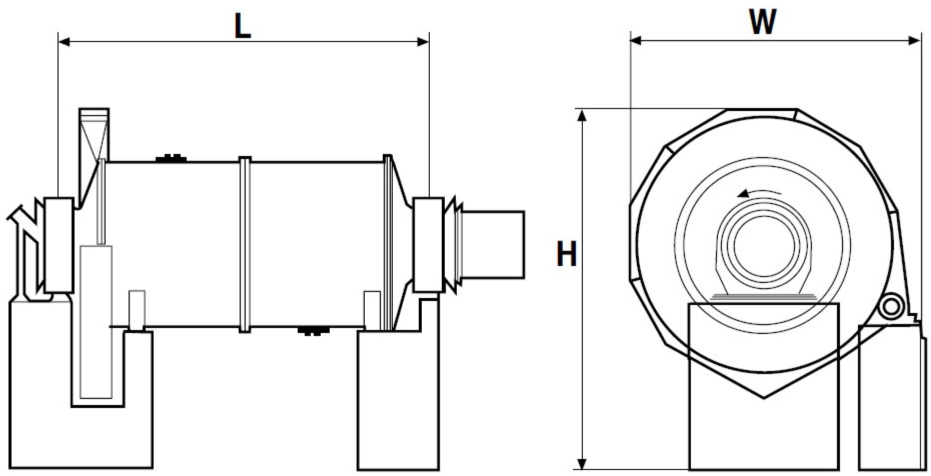
Ball mills



Ball mills

Standard Mill size (m)	Geared/Gearless	Std %TCS	Approx hp/kW	Motor hp/kW
9′ x 12′ (2,7x3,7)	Geared	76	388/290	450/335
9′ x 14′ (2,7x4,2)	Geared	76	455/340	500/373
9.5′ x 15′ (2,9x4,6)	Geared	76	564/420	600/447
10′ x 15′ (3,0x4,6)	Geared	76	596/445	700/522
10.5′ x 15′ (3,2x4,6)	Geared	76	734/547	800/597
10.5′ x 17′ (3,2x5,2)	Geared	76	836/623	900/671
11′ x 17′ (3,3x5,2)	Geared	76	944/704	1000/746
11.5′ x 18′ (3,5x5,5)	Geared	76	1125/839	1250/932
13′ x 17′ (3,9x5,2)	Geared	76	1460/1089	1500/1119
13′ x 19′ (3,9x5,8)	Geared	76	1637/1220	1750/1305
14′ x 18′ (4,2x5,5)	Geared	76	1877/1400	2000/1491
14′ x 20′ (4,2x6,0)	Geared	76	2091/1559	2250/1677
15′ x 19′ (4,6x5,8)	Geared	76	2372/1769	2500/1864
15.5′ x 21′ (4,7x6,4)	Geared	76	2861/2133	3000/2237
16.5′ x 21′ (5,0x6,4)	Geared	76	3362/2507	3000/2237
16.5′ x 24′ (5,0x7,3)	Geared	76	3854/2873	4000/2983
16.5′ x 27′ (5,0x8,2)	Geared	76	4346/3240	4500/3356
16.5′ x 30′ (5,0x9,1)	Geared	76	4838/3608	5000/3728
16.5′ x 33′ (5,0x10,0)	Geared	76	5330/3975	5500/4101
18′ x 29′ (5,5x8,8)	Geared	76	5847/4360	6000/4474
18′ x 31.5′ (5,5x9,6)	Geared	76	6360/4743	6000/4474
18′ x 33.5′ (5,5x10,2)	Geared	76	6771/5049	7000/5220

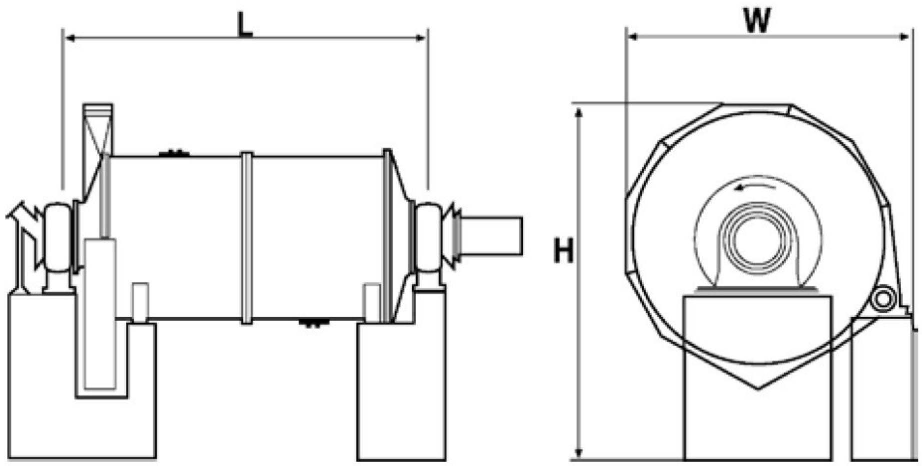
Ball mills (continue)



Ball mills (continue)

Standard Mill size (m)	Geared/Gearless	Std %TCS	Approx hp/kW	Motor hp/kW
20′ x 31.5′ (6x9,6)	Geared	76	8336/6212	8000/5966
20′ x 33.5′ (6x10,2)	Geared	76	8874/6617	9000/6711
21′ x 31.5′ (6,4x9,6)	Geared	76	9446/7044	10000/7457
21′ x 33.5′ (6,4x10,2)	Geared	76	10361/7726	11000/8203
22′ x 36.5′ (6,7x11,1)	Geared	76	12357/9215	13000/9694
22′ x 40.5′ (6,7x12,3)	Geared	76	13370/9970	14500/10813
24′ x 36′ (7,3x11)	Geared	76	15220/11350	16000/11931
24′ x 40′ (7,3x12,3)	Geared	76	16935/12628	17800/13273
26′ x 38′ (7,9x11,6)	Geared/Gearless	76	19720/14705	20700/15436
26′ x 40′ (7,9x12,3)	Geared/Gearless	76	20771/15489	21800/16256
26′ x 42′ (7,9x12,8)	Geared/Gearless	76	21823/16273	23000/17151
26′ x 44′ (7,9x13,4)	Geared/Gearless	76	22875/17058	24000/17897
27′ x 45′ (8,2x13,7)	Gearless	76	25763/19211	27000/20134
28′ x 46′ (8,5x14)	Gearless	76	28898/21549	30000/22371
29′ x 47′ (8,8x14,3)	Gearless	76	32291/24079	34000/25354
30′ x 46′ (9,1x14)	Gearless	76	34442/25683	36000/26845

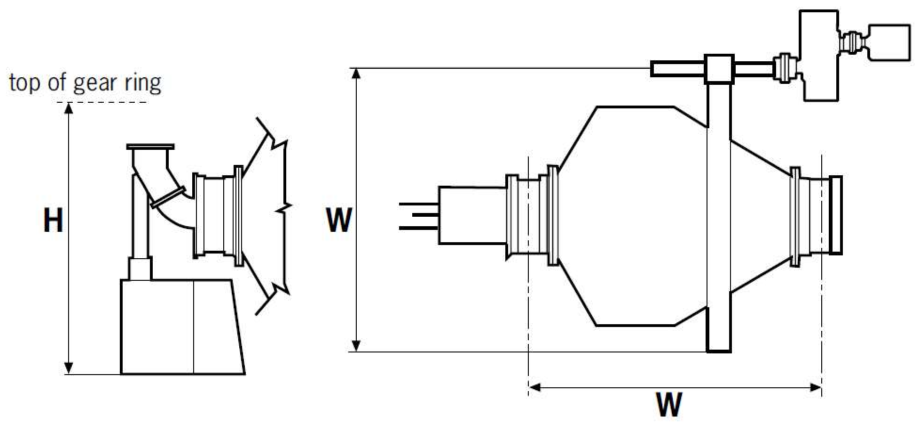
Spherical roller bearing supported ball mill



Spherical roller bearing supported ball mill

Mill size m (ft) DxL	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/HP
2.4x3.6 (8x11.8)	4350 (171)	5043 (199)	4650 (183)	232/311
2.4x4.2 (8x13.8)	4350 (171)	5643 (222)	4650 (183)	269/361
2.4x4.8 (8x15.7)	4350 (171)	6243 (246)	4650 (183)	306/410
2.8x4.2 (9x13.8)	4800 (189)	5874 (231)	5700 (225)	410/550
2.8x4.9 (9x16)	4800 (189)	6574 (259)	5700 (225)	474/636
2.8x5.6 (9x18.4)	4800 (189)	7274 (286)	5700 (225)	539/723
3.2x4.8 (10.5x15.7)	5200 (205)	6705 (264)	6790 (267)	643/863
3.2x5.6 (10.5x18.4)	5200 (205)	7505 (296)	6790 (267)	745/1000
3.2x6.4 (10.5x21)	5200 (205)	8317 (327)	6790 (267)	846/1135
3.6x5.4 (11.8x17.7)	5600 (221)	7548 (297)	7140 (281)	990/1327
3.6x6.3 (11.8x20.7)	5600 (221)	8448 (333)	7140 (281)	1145/1535
3.6x7.2 (11.8x23.6)	5600 (221)	9394 (370)	7140 (281)	1300/1743
4.0x6.0 (13x19.7)	7900 (311)	8425 (332)	9000 (355)	1452/1947
4.0x7.0 (13x23)	7900 (311)	9938 (391)	9000 (355)	1679/2251
4.0x8.0 (13x26)	7900 (311)	10425 (410)	9000 (355)	1905/2555
4.4x6.6 (14.4x21.7)	8000 (315)	9256 (364)	9500 (374)	2054/2754
4.4x7.2 (14.4x23.6)	8000 (315)	9856 (388)	9500 (374)	2229/2989
4.4x7.7 (14.4x25.3)	8000 (315)	10356 (408)	9500 (374)	2374/3184
4.4x8.2 (14.4x27)	8000 (315)	10856 (427)	5 700 (224)	2519/3379

Conical ball mill

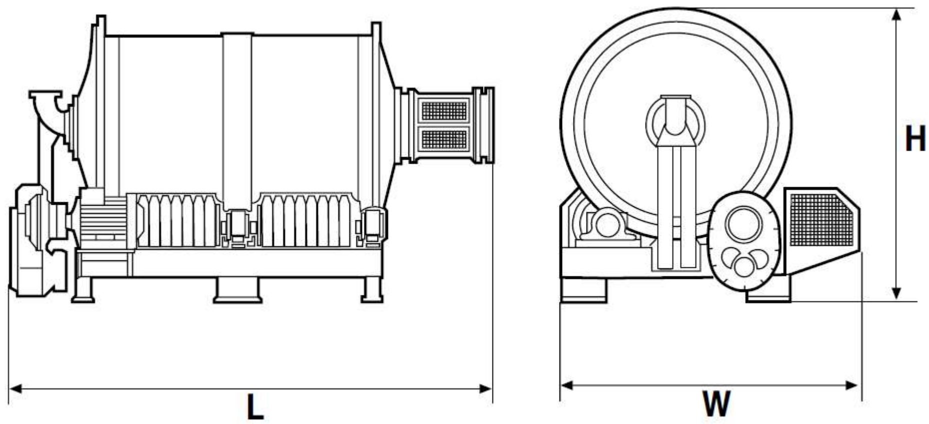


Conical ball mill

Mill size m (ft) DxL	H) mm (inch	L mm (inch	W mm (inch	Power motor kW/Hp
2.4x0.9 (8x3)	3 350 (132)	3 430 (135)	3 200 (126)	112/150
2.4x1.2 (8x4)	3 350 (132)	3 730 (147)	3 200 (126)	130/175
2.4x1.5 (8x5)	3 350 (132)	4 040 (159)	3 200 (126)	150/200
2.4x1.8 (8x6)	3 350 (132)	4 340 (171)	3 200 (126)	186/250
2.7x1.5 (9x5)	3 960 (156)	4 270 (168)	3 660 (144)	224/300
3.0x1.2 (10x4)	4 360 (168)	3 810 (150)	3 660 (144)	260/350
3.0x 1.7 (10x5.5)	4 360 (168)	4 110 (162)	3 860 (152)	300/400
3.0x1.8 (10x6)	4 360 (168)	4 420 (174)	3 860 (152)	336/450
3.0x2.1 (10x7)	4 360 (168)	4 720 (186)	3 860 (152)	373/500

SRR mill

Solid Rubber Roller



SRR mill

SRR Ball mill Mill size m (ft) DxL	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/Hp	Weight (empty) ton
0.6x0.9 (2x3)	1 110 (44)	1 830 (72)	1 220 (48)	2.2/3	0.9
1.0x1.5 (3.3x5)	1 635 (64)	2 700 (106)	1 850 (73)	11/15	2.4
1.2x2.4 (4x8)	1 970 (78)	3 670 (144)	2 740 (108)	30/40	5.6
1.5x3.0 (3.3x6.6)	2 255 (89)	4 550 (179)	3 150 (124)	75/100	9.2
1.8x3.6 (6x12)	2 660 (105)	5 560 (219)	3 500 (138)	132/177	12.8
2.1x3.6 (7x12)	3 150 (124)	5 830 (230)	4 400 (173)	132+75/ 177+100 *	22.0

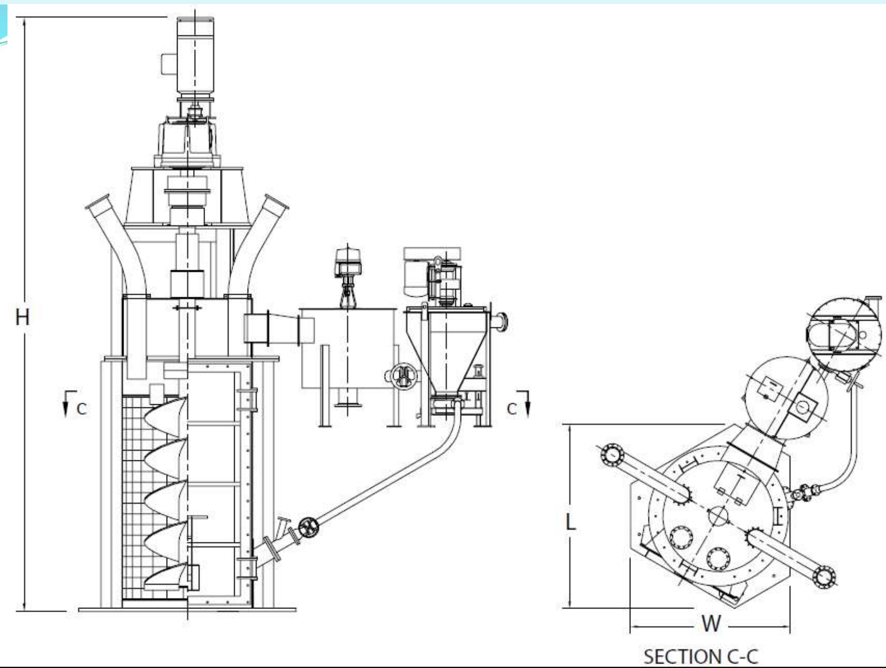
SRR Rod mill Mill size m (ft) DxL	H mm (inch)	L mm (inch	W mm (inch	Power motor kW/Hp	Weight (empty) ton
0.6x0.9 (2x3)	1 110 (44)	1 830 (72)	1 220 (48)	2.2/3	1.0
1.0x1.5 (3.3x5)	1 635 (64)	2 700 (106)	1 850 (73)	11/15	3.0
1.2x2.4 (4x8)	1 970 (78)	3 670 (144)	2 740 (108)	30/40	6.2
1.5x3.0 (3.3x6.6)	2 255 (89)	4 550 (179)	3 150 (124)	75/100	10.0
1.8x3.6 (6x12)	2 790 (110)	5 600 (220)	3 900 (154)	55+55/ 74+74*	14.5

**Dual drive*

VERTIMILL®

- Type **WB** (**W**et grinding – **B** design) is larger in diameter, but also have larger diameter, screw turning at lower speed and shorter overall height compared with the **LS** (Lime Slaking) type.
- They are designed to operate at full motor power.
- Ore bed lining.
- Regarding type LS for size reduction and slaking of lime.

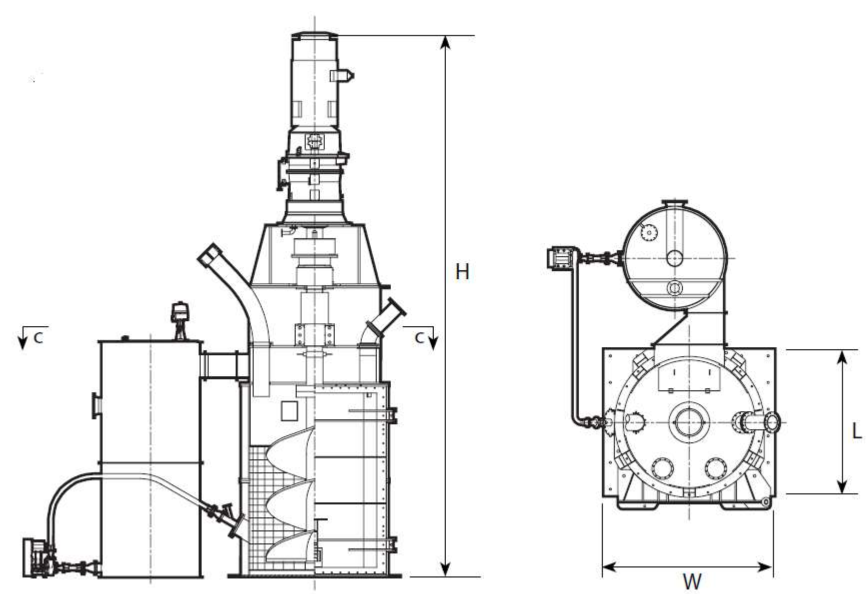
VERTIMILL®



VERTIMILL®

Model	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/Hp	Weight (empty) ton
VTM-15-WB	7 060 (278)	1 520 (60)	1 320 (52)	11/15	5.5
VTM-20-WB	7 180 (283)	1 520 (60)	1 320 (52)	15/20	5.9
VTM-40-WB	7 460 (294)	1 780 (70)	1 520 (60)	3040	8.2
VTM-60-WB	7 600 (299)	1 780 (70)	1 520 (60)	45/60	8.8
VTM-75-WB	7 900 (311)	1 960 (77)	1 700 (67)	56/75	12.5
VTM-125-WB	9 270 (365)	2 670 (105)	2 310 (91)	93/125	17.9
VTM-150-WB	9 780 (385)	2 670 (105)	2 310 (91)	112/150	19.6
VTM-200-WB	9 780 (385)	2 670 (105)	2 310 (91)	150/200	20.5
VTM-250-WB	9 650 (380)	3 660 (144)	3 180 (125)	186/250	33.8
VTM-300-WB	9 650 (380)	3 660 (144)	3 180 (125)	224/300	35.7
VTM-400-WB	11 320 (446)	3 910 (154)	3 380 (133)	298/400	52.7
VTM-500-WB	12 070 (475)	3 860 (152)	3 780 (149)	373/500	66.1

VERTIMILL®



Section C-C

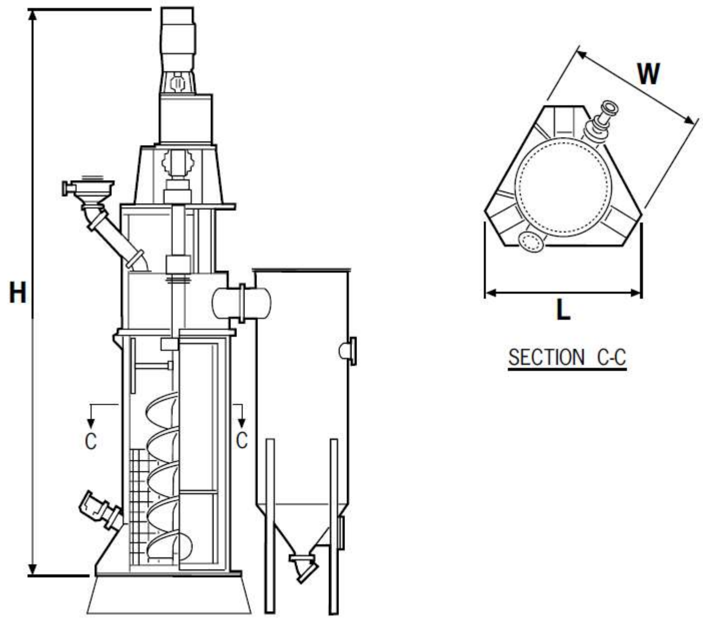
VERTIMILL®

Model	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/Hp	Weight (empty) ton
VTM-650-WB	12 270 (483)	3 250 (128)	3 860 (152)	485/650	82.6
VTM-800-WB	13 460 (530)	3 560 (140)	4 060 (160)	597/800	100.4
VTM-1000-WB	13 460 (530)	3 660 (144)	4 270 (168)	746/1 000	116.1
VTM-1250-WB	13 460 (530)	4 090 (161)	4 520 (178)	932/1 250	125.4
VTM-1500-WB	14 220 (560)	4 370 (172)	4 570 (180)	1 118/1 500	167.0
VTM-3000-WB	17 590 (692)	6 820 (268)	6 880 (271)	2 237/3 000	343.0
VTM-4500-C	18 600 (732)	6 820 (268)	6 880 (271)	3355/4500	367.0

VERTIMILL®

- **Type LS (Lime Slaking) for size reduction and slaking of lime**
- Regarding type WB (Wide body) for grinding operations only.

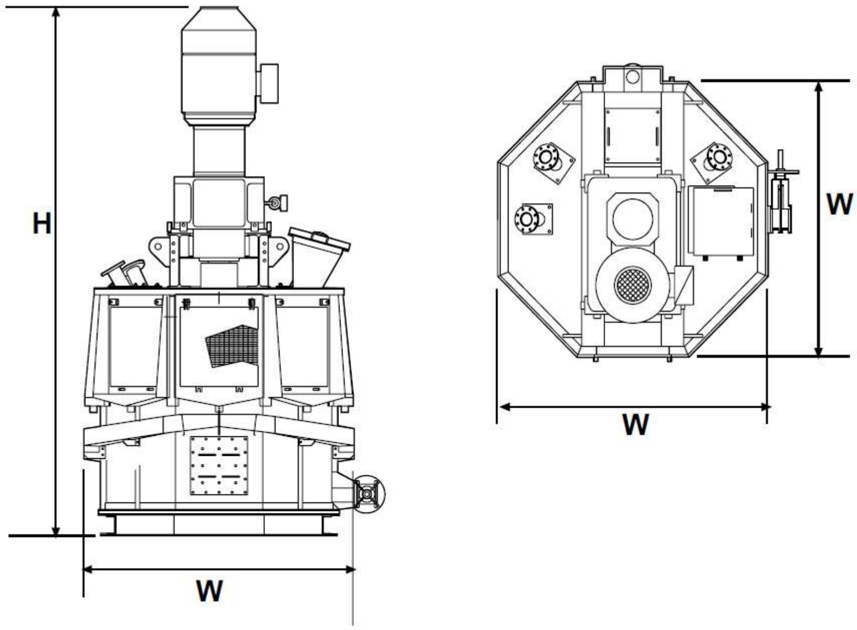
VERTIMILL®



VERTIMILL®

Model	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/Hp	Weight (empty) ton
VTM-20-LS	7 060 (278)	1 520 (60)	1 320 (52)	15/20	5.5
VTM-30-LS	7 180 (283)	1 520 (60)	1 320 (52)	22/30	5.9
VTM-50-LS	7 460 (294)	1 780 (70)	1 520 (60)	37/50	8.2
VTM-100-LS	7 900 (311)	1 960 (77)	1 700 (67)	45/60	8.8
VTM-150-LS	8 740 (344)	2 670 (105)	2 310 (91)	75/100	12.5
VTM-200-LS	9 780 (385)	2 670 (105)	2 310 (91)	112/150	17.9
VTM-300-LS	10 160 (400)	3 660 (144)	3 180 (125)	150/200	19.6
VTM-400-LS	11 320 (446)	3 910 (154)	3 380 (133)	224/300	50.0

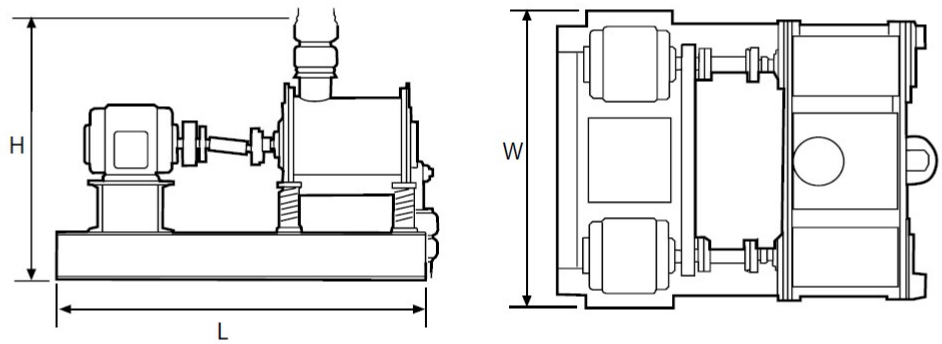
Stirred media grinding mill



Stirred media grinding mill

Model	Power motor kW (HP)	H mm (inch)	W mm (inch)	Weight (empty) kg (lb.)
SMD-90	90 (120)	4215 (166)	2130 (84)	4020 (8 863)
SMD 185	185 (250)	4 350 (171)	2 275 (90)	7 200 (15 875)
SMD 355	355 (475)	5 990 (236)	2 800 (110)	13 450 (29 650)
SMD 1100	1 100 (1475)	4 825 (190)	4 220 (166)	27 500 (60 630)

Vibrating ball mill



Vibrating ball mill

Model	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/Hp	Weight (empty) ton
VBM 1518*	1 120 (44)	1 780 (70)	1 350 (53)	2x5.6/2x7.5	1.2
VBM 3034**	1 680 (66)	2 790 (110)	2 130 (84)	2x37/2x50 6.2	

* Grinding chamber diameter15"(380mm), length 18"(460mm)

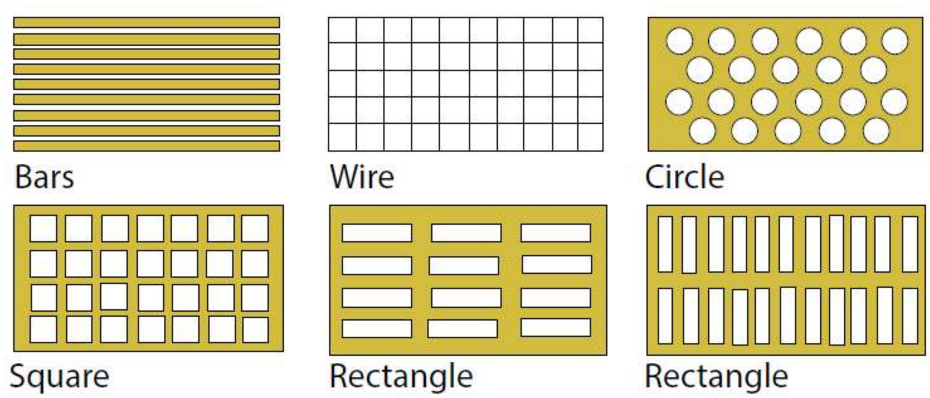
** Grinding chamber diameter30"(760mm), length 34"(860mm)

Size control by methods

- In mineral processing practices we have two methods dominating size control processes: Screening & Classification

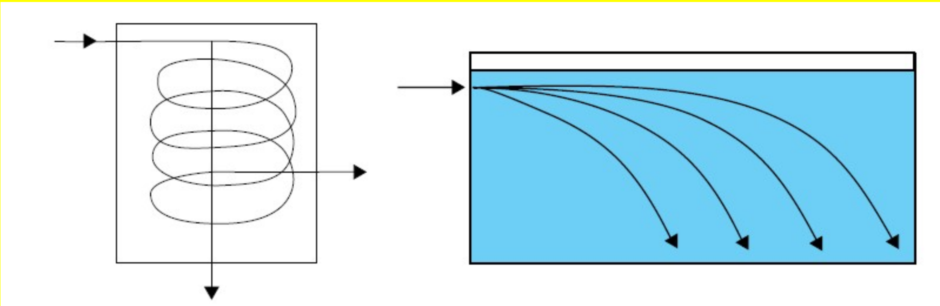
Screening

- Screening using a geometrical pattern for size control.



Classification

❑ Classification using particle motion for size control.



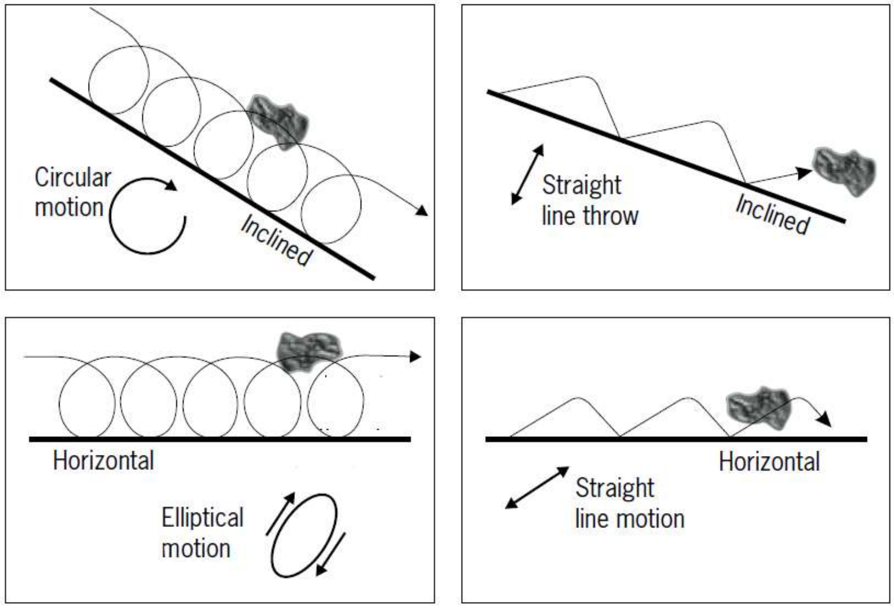
Screens

❑ Performance of screens will fall back on three main parameters:

Motion – Inclination – Screening media

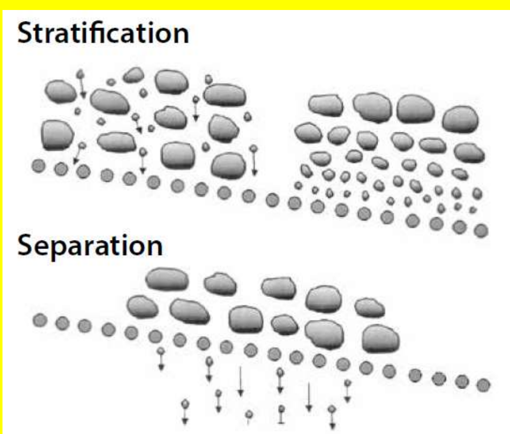
fall back: کاهش یافتن، پایین آمدن

Screen motions



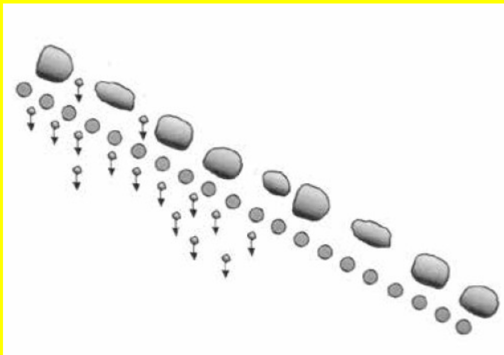
Screening by stratification

- By building up a material bed on a screen deck the material will stratify when the motion of the screen will reduce the internal friction in the material.
- This means that the finer particles can pass between the larger ones giving a sharp separation.



Screening by free fall

- If we use the double inclination used for stratification (from 10-15 up to 20-30 degrees) we are in free fall, meaning that no particle layer can build up on the screen deck.
- The particles will now be sized directly via the screening media, giving a higher capacity, (or a more compact installation), but also less sharpness in separation.
- Optimal use when a large amount of fines shall be removed fastly.



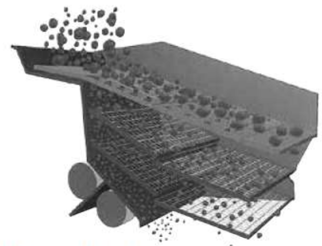
Screen types

- There are many types of screens, but they can be reduced to the four types shown below.
- Of these types approx. 80 % used worldwide are of type single inclination, stratification screens.
- The other are of type double, triple or multiple inclination, where screening by stratification and free fall are combined for different applications.

Screen types

Single inclination

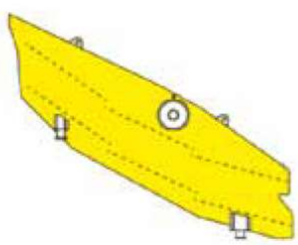
- Stratification screen
- Circular (15 deg.)
- Linear 0 – 5 (deg.)
- Still the leader in selective screening



Double inclination

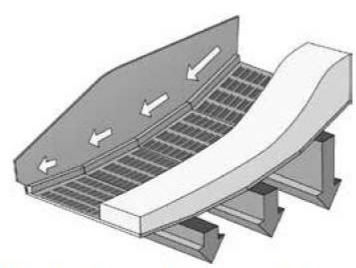
- Free fall
- Compact - high capacity paid for by lower selectivity
- Typical in circuit screening

Screen types



Triple inclination

- Combine capacity and selectivity
- Typical control screen for advanced product fractions



Multiple inclination ("banana screen")

- Effective "Thin-layer" screen
- Popular in coal and metallic mining

Screen capacities

- Sizing of screens is a time consuming process to be done by specialists.
- To get an idea about capacities we can use the figures below.
- They refer to screening by stratification using wire mesh as screening media.

Screen capacities

Feed through screen deck (t/h)				
Separation (mm)	3.6 x 1.5 m 5.4 m^2	4.2 x 1.8 m 7.6 m^2	4.8 x 2.1 m 10.0 m^2	6.0 x 2.4 m 14.4 m^2
2	20	30	45	65
5	50	70	95	135
8	75	105	140	180
12	100	145	200	230
16	125	180	230	270
25	175	250	300	350
32	200	290	350	400
50	270	370	430	500
90	370	460	550	640

Example:

Single deck screen. Feed size 50% - 2 mm. Feed capacity 90 t/h, cut 2 mm.

Select: a 10 m^2 screen deck.

Selection of screening media

- ❑ Selection of the correct size and type of screen is important.
- ❑ Equally important is the selection of the screening media.
- ❑ This refers not only to a correct aperture related to the "cut size", but also to the wear in operation of these screens.
- ❑ Below a short selection guide to screening media can be found.

Rubber or polyurethane?

Feed size	Select	Because
>35 mm dry	Rubber 60 sh	Absorbes impact Resistant to sliding abrasion
<0-50 mm wet	Polyurethane	Very good against sliding abrasion Accurate separation
<40 mm dry/moist	Rubber 40 sh (soft)	Very flexible Prevents blinding
Look out for:	Oil in rubber applications Hot water or acids in PU-applications	

Selection of screening media

What thickness?

General rule for min. thickness

$$\frac{\text{Max feed size}}{4} = \text{Panel thickness}$$

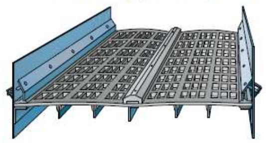
What happens if we go...?

THINNER		THICKER
+	Capacity	–
+	Accuracy	–
–	Service life	+
–	Blinding/Pegging Tendency	+

N.B.: Thickness should not exceed required product size

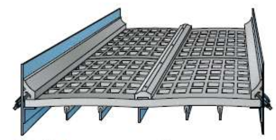
Selection of screening media

What type of panel

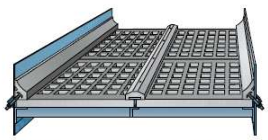


Tension mats with hooks *fits all screens designed with cambered decks and tensioning rails.*

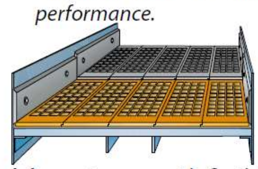
Wire mesh panels *offer superior open area and are quickly available.*



Bolt down panels*, pre-tensioned for easy installation and guaranteed screening performance.*



Self supporting panels*, for screens of open frame design for tough applications .*

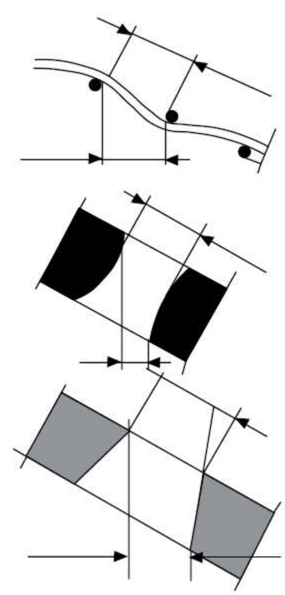


Modular systems *provide flexibility in wear material/hole configuration combinations.*

camber: /ˈkæmbər/ خمیدگی اندک، تحدب کم

Selection of screening media

What hole size? (Inclined deck)



General guideline for wire mesh:

"Required product size plus 5 – 10%"

General guideline for rubber panels:

"Required product size plus 25 – 30%"

General guideline for PU panels:

"Required product size plus 15 – 20%"

Selection of screening media

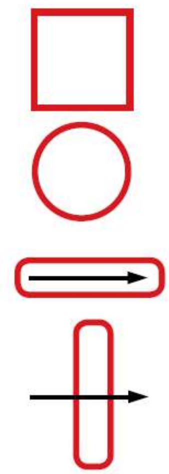
What type of hole?

The standard choice

For improved service life (coarse screening)

For improved capacity

For improved accuracy and dewatering



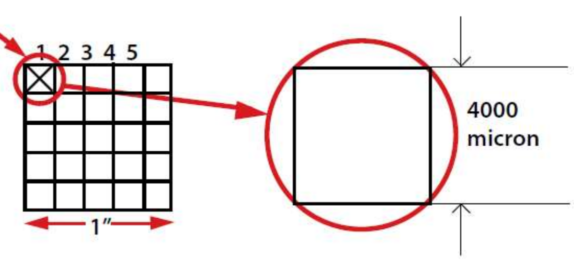
Particle size – Mesh or Micron?

Particle size – Mesh or Micron?

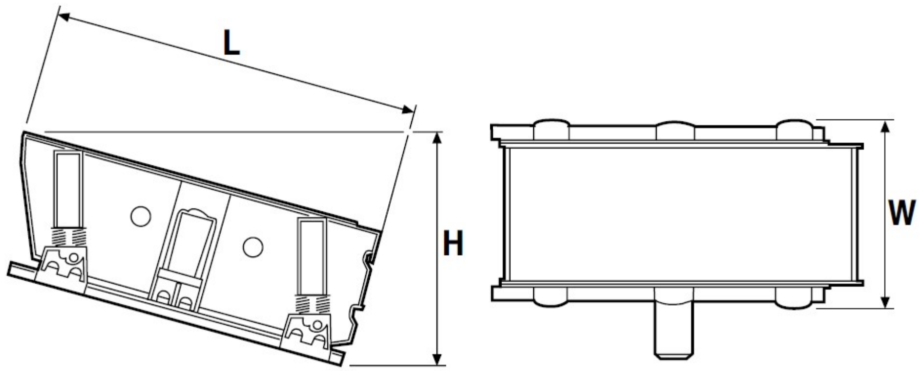
mesh*	micron	mesh	micron	mesh	micron
2½	8000	14	1180	80	180
3	6700	16	1000	100	150
3½	5600	20	850	115	125
4	4750	24	710	150	106
5	4000	28	600	170	90
6	3350	32	500	200	75
7	2800	35	425	250	63
8	2360	42	355	270	53
9	2000	48	300	325	45
10	1700	60	250	400	38
12	1400	65	212	500	25

*Taylor serie (US)

Mesh number = the number of wires per inch or the number of square apertures per inch



Single inclination screen – Circular motion



Single inclination screen – Circular motion

Dimensions at 15° inclination

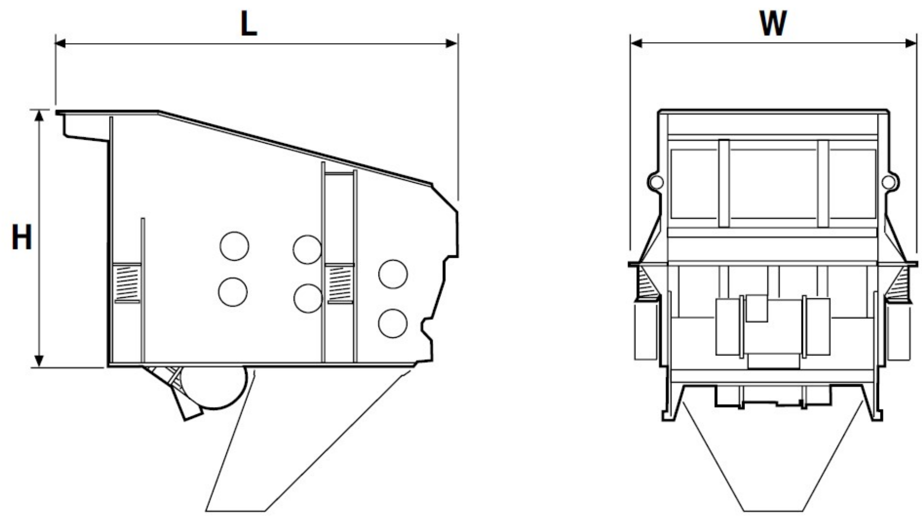
Model	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/hp	Weight ton
VFS 36/15 2d	2 700 (106)	4 465 (176)	2 230 (88)	11/15	3.7
VFS 42/18 2d*	2 965 (117)	5 065 (199)	2 530 (100)	15/20	4.5
VFS 48/21 2d	3 100 (122)	5 665 (223)	2 830 (111)	18.5/25	5.5
VFS 36/15 3d	3 065 (121)	4 465 (176)	2 230 (88)	15/20	4.7
VFS 42/18 3d	3 220 (127)	5 065 (199)	2 530 (100)	18.5/25	5.8
VFS 48/21 3d	3 530 (139)	5 665 (223)	2 830 (88)	22/30	7.5
VFSM 42/18 2d**	2 900 (114)	5 200 (205)	2 530 (100)	18.5/25	5.6
VFSM 48/21 2d	3 050 (120)	5 800 (228)	2 830 (111)	22/33	7.0
VFSM 60/24 2d	3 550 (140)	7 000 (276)	3 340 (131)	2x18.5/2x25	10.8
VFSM 48/21 3d	3 425 (135)	5 800 (228)	2 830 (88)	2x18.5/2x25	8.5
VFSM 60/24 3d	4 305 (170)	7 000 (276)	3 340 (131)	2x22/2x33	14.2

* VFS 42/18 2d = screen deck dimension 4.2m x1.8m (165"x70"), double deck

**VFSM 42/18 2d = same as above but heavy duty version

Screening area calculated from screen type ex. VFS 42/18; 4.2x1.8 = **7.6 m² x11= 82ft²**

Double inclination screen – Linear motion

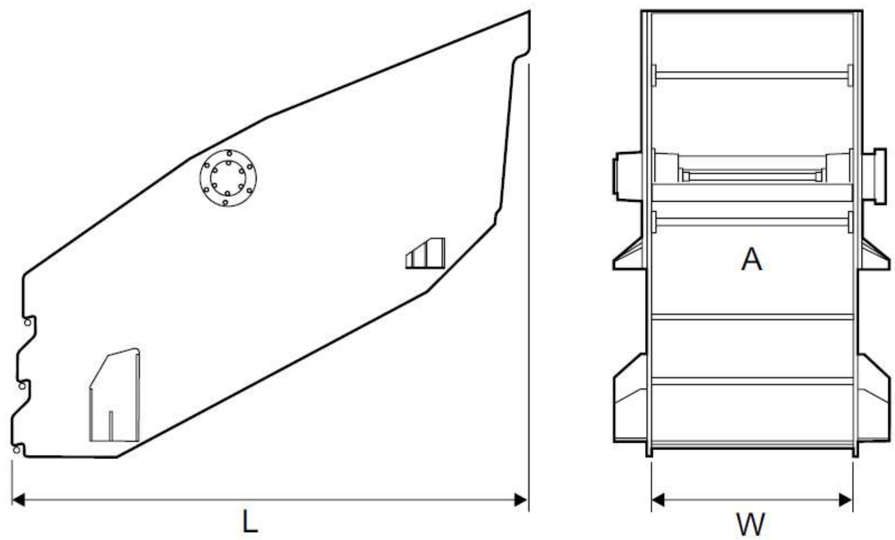


Double inclination screen – Linear motion

Model	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/hp	Weight ton	Max feed mm/inch
VFO 12/10 2d	1 450 (57)	1 330 (52)	435 (17)	2x1.3/2x1.7	1.0	120/5
VFO 20/12 2d	1 515 (60)	2 380 (94)	1 700 (67)	2x2.3/2x3.1	1.6	150/6
VFO 20/12 3d	1 515 (60)	2 380 (94)	1 700 (67)	2x2.3/2x3.1	1.7	150/6
VFOM 12/10 3d*	1 390 (55)	1 460 (579	1 426 (56)	2x2.3/2x3.1	1.3	300/12
VFOM 20/12 3d	1 915 (75)	2 980 (117)	1 720 (68)	2x4.0/2x5.4	2.7	300/12

* VFOM, heavy-duty version with dual springs at feed and discharge ends

Triple inclination screen – Linear motion

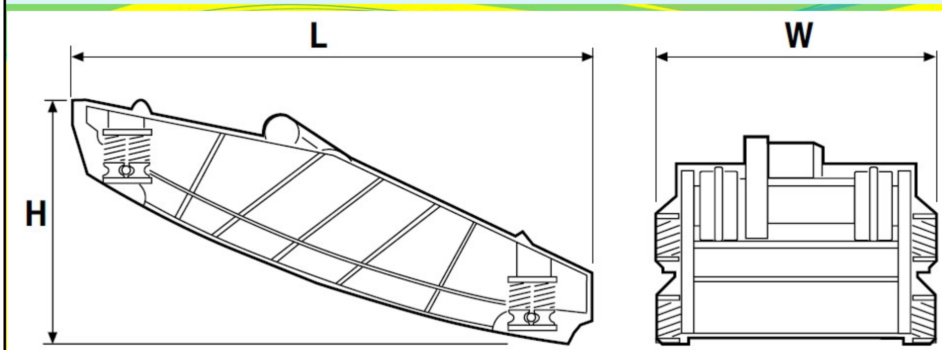


Triple inclination screen – Linear motion

Model	L mm (inch)	W mm (inch)	A m^2 (Sq. ft.)	Power motor kW /HP	Weight ton
TS 2.2*	5 830 (230)	1 530 (60)	7.5 (80)	15/20	6
TS 2.3*	5 830 (230)	1 530 (60)	7.5 (80)	15/20	8
TS 3.2	6 330 (249)	1 839 (72)	11 (116)	22/30	8
TS 3.3	6 330 (249)	1 839 (72)	11 (116)	22/30	10
TS 4.2	6 350 (250)	2 445 (96)	15 (156)	30/40	9
TS 4.3	6 350 (250)	2 445 (96)	15 (156)	30/40	12
TS 5.2	8 595 (338)	2 445 (96)	20 (215)	30/40	16
TS 5.3	8 595 (338)	2 445 (96)	20 (215)	2x22/2x30	20
TS 6.2	8 734 (344)	3 045 (120)	25 (269)	2x22/2x30	20
TS 6.3	8 736 (344)	3 045 (120)	25 (269)	2x30/2x40	24

* TS 2.2 = 2 decks and TS 2.3 = 3 decks screen

Multiple inclination screen – Linear motion (Banana screen)



Model	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/hp	Weight ton
MF 1800x6100 1d	2 703 (107)	6 430 (253)	2 555 (101)	22/30	6.7
MF 2400x6100 1d	2 691 (106)	6 431 (253)	3 166 (125)	30/40	8.5
MF 3000x6100 1d	2 897 (114)	6 614 (260)	3 774 (149)	45/60	11.5
MF 3000x6100 2d	4 347 (171)	6 759 (266)	3 774 (149)	45/60	17.0

Classification – Introduction

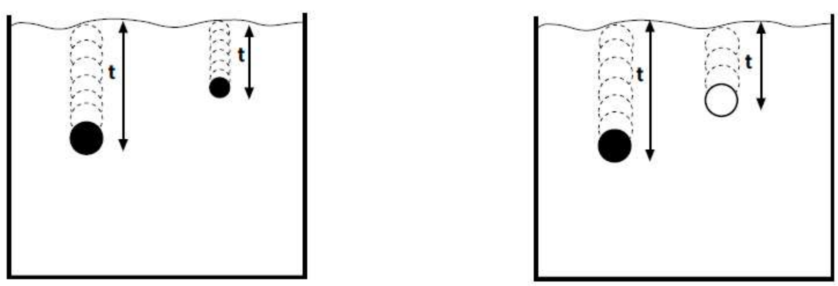
- For size control of particles **finer than 1 mm**, we are moving out of the practical range of conventional screens.
- Classification is the process of separating particles by size into two or more products according to their behavior in air or water (liquids).

Classification – Introduction

❑ **Classification methods:**

- Wet classification with **hydrocyclones** using separation by centrifugal force covering the size range of 10–100 micron (typical)
- Wet classification with **spiral classifiers** using separation by gravity covering the size range of 100 – 1000 micron (typical)
- Dry classification using separation by **centrifugal force** covering the range of 5 – 150 micron (typical).

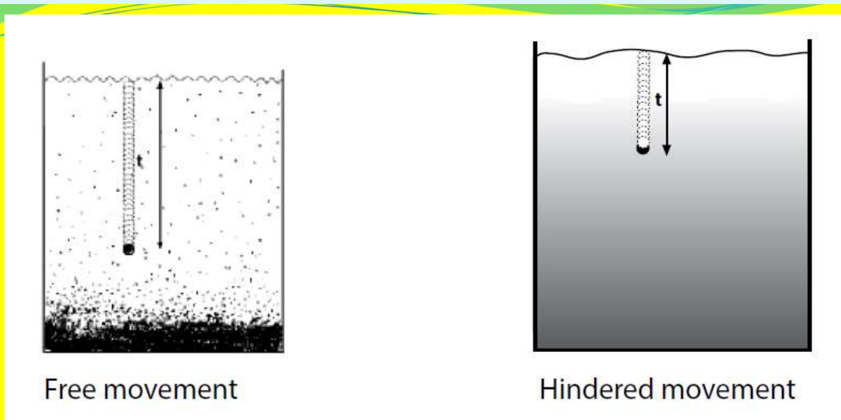
Wet classification – fundamentals



Coarse particles move faster than fine particles at equal density

High density particles move faster than low density particles at equal size

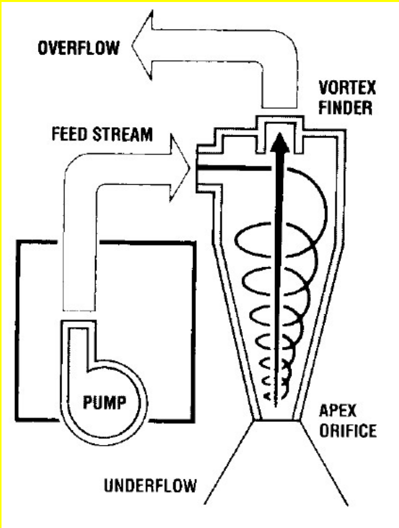
Wet classification – fundamentals



- If a particle has no interference from other particles it moves faster than a particle surrounded by other particles due to increased density and viscosity of the slurry.
- This is called free and hindered movement and is valid both for gravity and centrifugal classification.

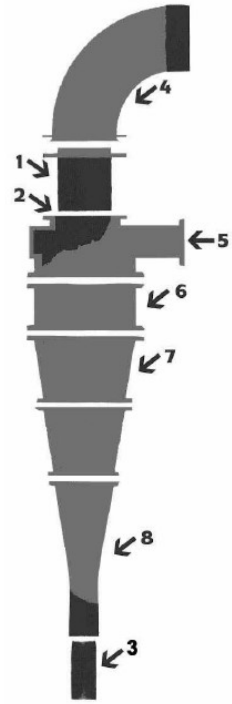
Hydrocyclone

- Centrifugal forces classify solids by size (mass).
- High mass particles closer to outer wall reporting to underflow.
- Low mass particles closer to the center reporting to overflow.



Hydrocyclone design

- ❑ 1. Vortex finder
- ❑ 2. Inlet head
- ❑ 3. Spigots (apex)
- ❑ 4. Overflow elbow
- ❑ 5. Feed inlet
- ❑ 6. Barrel
- ❑ 7. Cones
- ❑ 8. Cone extension



Hydrocyclone applications – more than size control

❑ Although the hydrocyclone by nature is a size controlling machine, the number of applications in mineral are many:

- Classification in grinding circuits
- Dewatering and thickening
- Desliming and washing
- Enrichment of heavy minerals (DMS) (dense medium separation)
- a.o.

Spiral classifier

- By combining a gravity settler of rectangular section with a sloped transport spiral for the sediment – we have a spiral classifier.

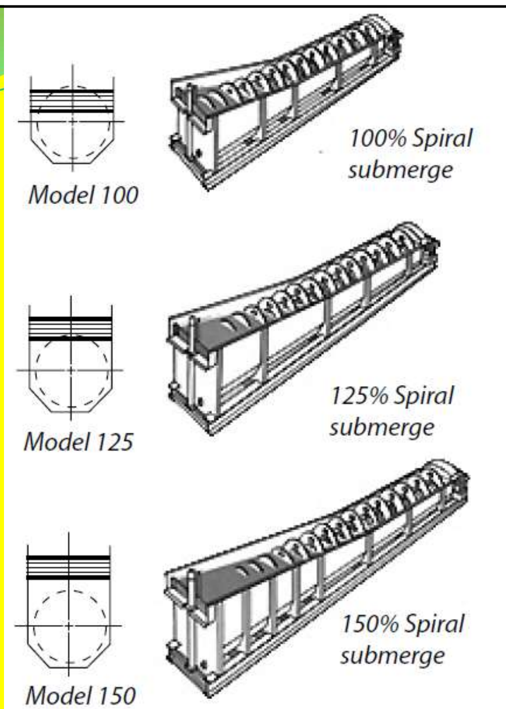
Spiral classifier – Nomenclature

24" Model 100-MF-SP

- Pitch – Single (SP) or Double (DP)
- Tank Style – Straight (ST), Modified Flare (MF) and Full Flare (FF)
- Spiral Submergence Model – 100%, 125% or 150%
- Spiral Diameter

sub·merge /səbˈmɜːdʒ $ -ˈmɜːrdʒ/: غوطه‌ور ساختن، در آب فرو بردن

Spiral classifier

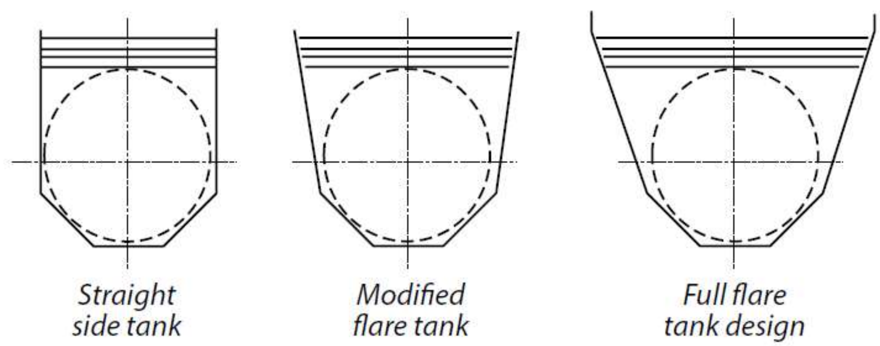


Spiral classifier – Design

- ❑ By combining the proper submergence of the spiral as shown in the drawings of the three models at right with one of the three tank designs a choice of combinations are possible.
- ❑ Thus the selection can be tailored to suit each problem.
- ❑ The proper combination of pool depth, area and spiral construction, result in controlled turbulence for accurate size separations or efficient washing or dewatering as desired.
- ❑ The required pool area is balanced with the sand raking capacity of the spiral by the design of the tank.
- ❑ Tank designs to suit specific applications are shown below.

tai·lored /ˈteɪləd $ -ərd/: fit مناسب، درخور، جورشده،

Spiral classifier – Design

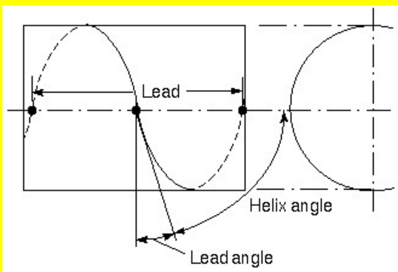


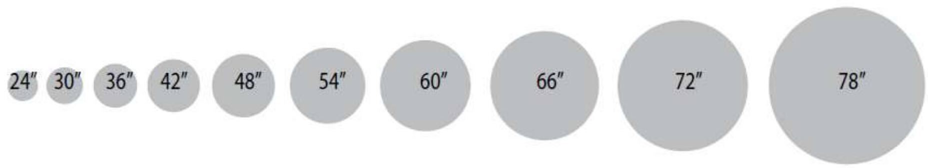
Spiral classifier – Design

- **Straight side:** For coarse separations.
- **Modified flare:** Increases pool area for intermediate to fine separations and for washing and dewatering.
- **Full flare:** Maximum pool area for fine to very fine separations and for washing and dewatering where large volumes of water are to be handled.
- Sand raking and conveying is usually a major consideration in any classifier application, and the full range of spiral diameters available cover all requirements.

Spiral classifier – Design

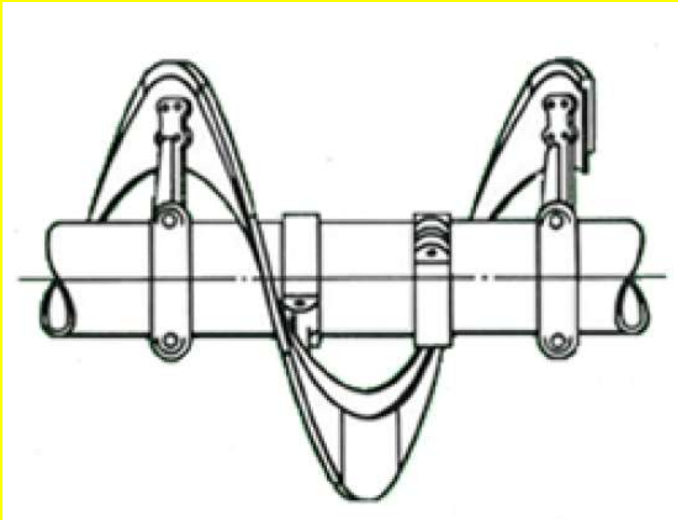
- Each of these units is designed for high efficiency and greater raking capability due to the increased lead or helix angle of the spiral.
- This increased lead angle results in improved conveying efficiency and greater conveying capacity.





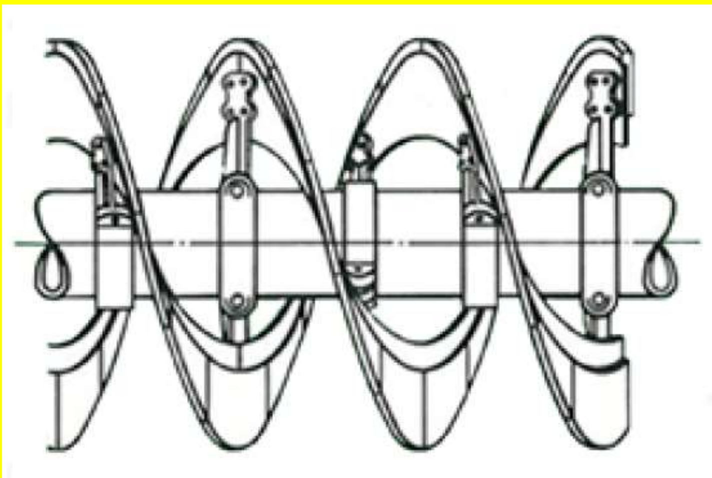
Spiral classifier – Design

- **Single pitch:** Single pitch spirals are available on all sizes of classifier and consist of one continuous spiral ribbon.



Spiral classifier – Design

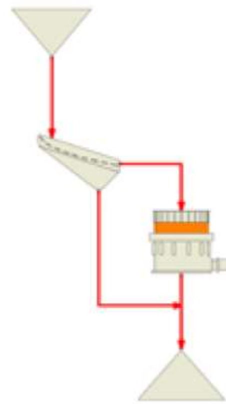
- **Double pitch:** The double pitch spiral has twice the raking capacity of a single pitch assembly and consists of two duplicate spiral ribbons.
- This construction is available for all sizes of classifier.



Size control in crushing and grinding circuits

Crushing circuits – Open screening

- Screening ahead of a crusher avoids packing
- Less wear in the crusher
- Higher total capacity
- The screening media is "controlling" the product in two dimensions. No "flaky shortcuts".

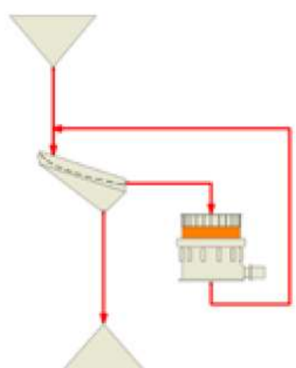


/ˈfleɪki/ لایه لایه

Size control in crushing and grinding circuits

Crushing circuits – Closed screening

- The screens are lowering the capacity
- Calibration of the product is improved
- Better cubical shape
- Higher reduction ratio

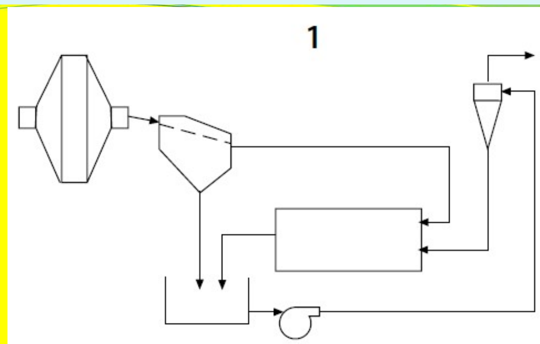


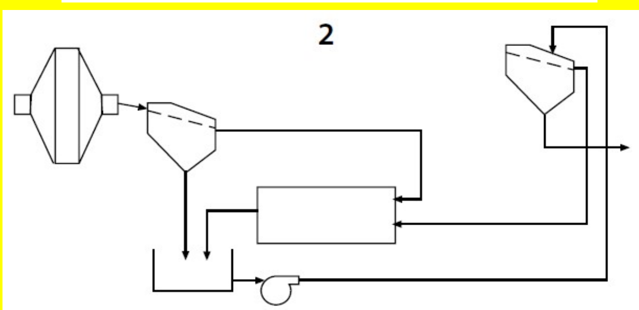
Grinding circuits – Screening

- Used for "trapping critical sizes" in AG - SAG circuits (1)
- Used for taking out size fractions from AG circuits for pebble grinding (1)
- Used in circuits with heavy minerals – avoiding over grinding (fine screening) (2)
- Screens being static (fixed cut point) are not too tolerant to changes in product size, causing variations in circulating loads.
- Mechanical damage or clogging of screening media can disturb operation.

clogging: انسداد لوله بر اثر خوردگی، گرفتگی

Grinding circuits – Screening

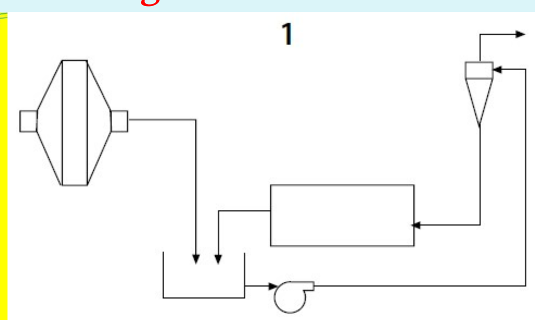


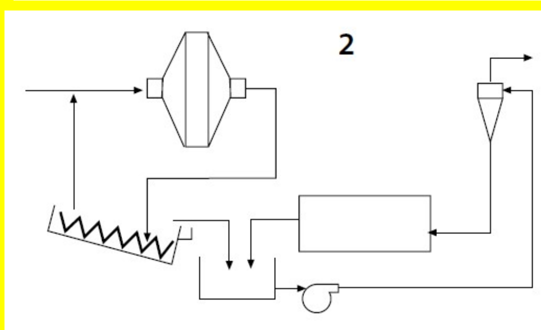


Grinding circuits – Classification

- ❑ Classifiers being dynamic (floating cut point) are more tolerant to changes in product size as the cut point is moving with the changes.
- ❑ Cyclones, being most common, are effective as classifiers at cut points below 300 microns (1)
- ❑ Spiral classifiers are effective as classifiers at cut points up to 800 microns.
- ❑ For the coarse fraction solids up to 50mm (2″) can be removed by the spiral.
- ❑ Spiral classifiers and cyclones can be used complementary if cut point is coarser than 200 microns. (2)

Grinding circuits – Classification





Wear in operation

- Mineral processing activities unavoidably result in wear. And wear costs money. Often lots of money. This is related to the structure of rock, ore or minerals, being crystals normally both hard and abrasive.

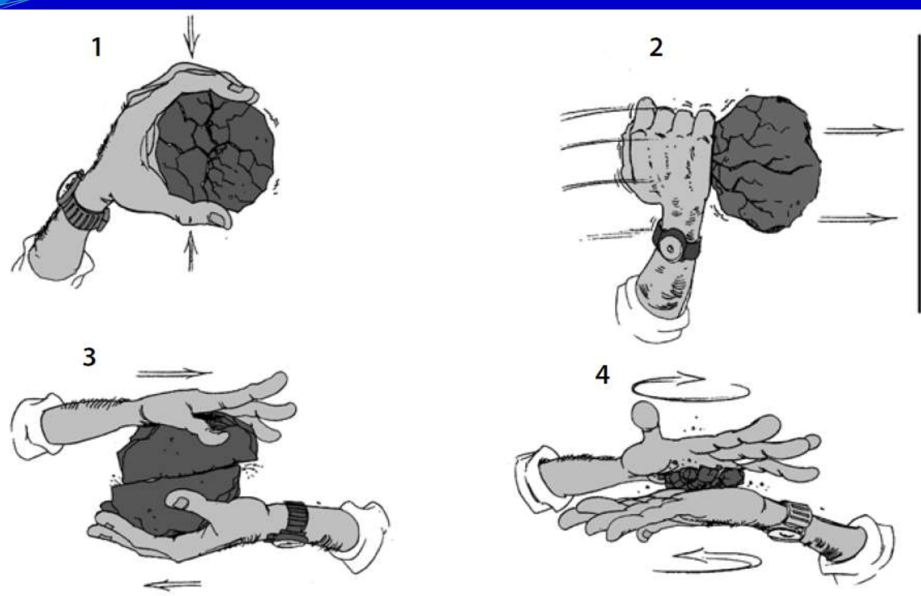
Why wear at all?

Wear is caused by the normal rock stress forces

- Compression (1)
- Impaction (2)
- Shearing (3)
- Attrition (4)

in combination with **mineral abrasion, hardness and energy!**

Wear in operation



Wear in operation

Wear in operation

caused by

COMPRESSION	IMPACTION HIGH VELOCITY >7m/s	IMPACTION LOW VELOCITY <7m/s	SLIDING

METALS
- Manganese steel
- Cr-MO steel
- High crome Cr white iron
- Ni hard Ni-Cr white iron

protected by

Polymers
- Rubber
- Polyurethane

CERAMICS

Wear by compression

COMPRESSION	IMPACTION HIGH VELOCITY >7m/s	IMPACTION LOW VELOCITY <7m/s	SLIDING

Metals
- Manganese steel
- Ni hard Ni-Cr white iron
- High crome Cr white iron

Applications:

Crushers: Gyratory, Cone, Jaw

Metals and compression خودترمیمی

Manganese steel: The first option for compression wear is manganese steel. This alloy has a very special property, being self hardening and self healing when exposed to large amounts of compression and impact energy.
Normal standard is a 14% Mn alloy which is first option in most crushing applications.
18 % Mn alloy is a harder but also a more brittle alloy used in applications where the rock is softer (limited self hardening) but very abrasive.

Restrictions:
When installed in applications without work hardening service life will be poor!

The alloys of cast "white iron" type (High-chrome and Ni-hard) shall be avoided in crushers submitted to heavy compression.

Wear by impaction (high)

COMPRESSION | IMPACTION HIGH VELOCITY >7m/s | IMPACTION LOW VELOCITY <7m/s | SLIDING

Metals
- Manganese steel
- Ni hard Ni-Cr white iron
- High crome Cr white iron

Applications:

Impactors { HSI, VSI }

Grinding mills

Slurry pumps

Metals and impaction

The metals can be classified as:

Manganese: Needs high impaction for self hardening. If impaction is getting lower and sliding is increasing Manganese is not suitable.
High Chrome: Opposite to manganese, can take heavy sliding but is more fragile and therefore limited against impaction.
Ni-hard: Somewhere between the two materials above.
Cr-Mo: Used in grinding when High Chrome is too brittle

Note! *The use of chrome steel (less brittle than chrome iron) is increasing for liners, curtains and hammers.*

Poly-Met: A combination of rubber and wear resistant metallic alloys is often an alternative to an all metallic lining in high impact grinding mills as the rubber will absorb the impact and prevent cracking of the metal.

Wear by impaction (low)

COMPRESSION | IMPACTION HIGH VELOCITY >7m/s | IMPACTION LOW VELOCITY <7m/s | SLIDING

Rubber and impaction
For low velocity impaction (material speed less than 7 m/s) wear resistant rubber is always the first choice and will give the best cost effectiveness. The material is also very tolerant to material size and is excellent for use in grinding mills, dump trucks and primary hoppers.

The rubber compound is selected to suit the specific application.

Restrictions:
Look out for aromatic and fuel oils.
Impact angles have to be considered, see 9:4.

Polymers
- Rubber
- Polyurethane

CERAMICS

Applications:
Dump Trucks, Feeder hoppers, Transfer points, Grinding Mills
Slurry pumps

Wear by sliding

pol·y·u·re·thane /ˌpɒlɪˈjʊərəθeɪn $ ˌpɑːlɪˈjʊr-/

COMPRESSION | IMPACTION HIGH VELOCITY >7m/s | IMPACTION LOW VELOCITY <7m/s | SLIDING

Rubber and sliding
Wear resistant rubber is an outstanding option for the sliding abrasion of small, hard and sharp particles. Also for wet conditions.

Restrictions:
If sliding speed is exceeding 7 m/s (dry applications) temperature can start to rise and cause damage. Besides temperature oil is always a threat.

Polyurethane and sliding
Best option for tough sliding applications when particle size is lower than 50 mm. Excellent in wet applications. Tolerant to chemicals and oil.

Restrictions:
Large sizes and high velocity might cause problems.

Polymers
- Rubber
- Polyurethane

CERAMICS

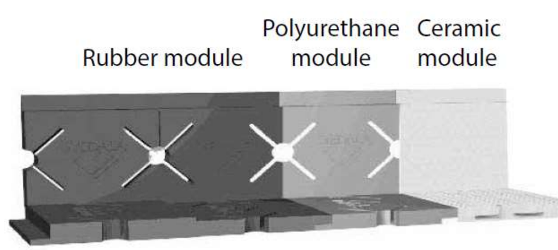
Applications:
Chutes, Spouts

Ceramics and sliding
The natural choice when mission is too hard for the options above. Hardness, resistance to temperature and corrosion plus low weight gives a masterpiece for sliding.
Al_2O_3 (Aluminum oxide) is the most cost-effective material.

Restrictions:
Impaction is dangerous for ceramics (cracking) and must be avoided. Combination ceramics + rubber is an option. Composition and quality can vary from supplier to supplier.

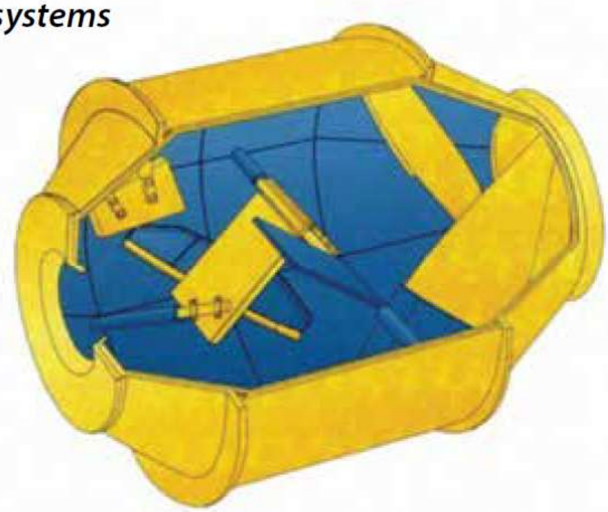
Wear protection – Wear products

Modules
Sheets, elements and profiles

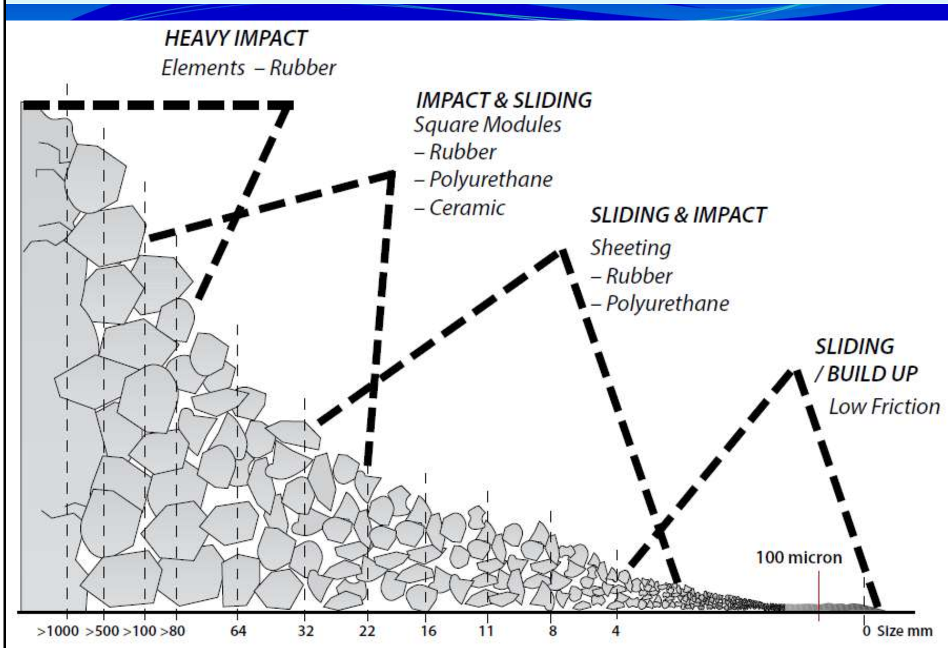


Wear protection – Wear products

Customized lining systems



Wear products – applications

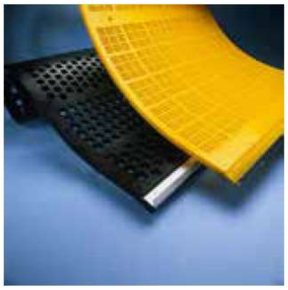


Wear protection – Wear parts

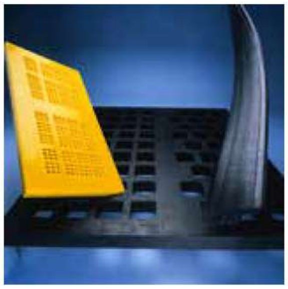
- Wear parts – Screening

Self supporting rubber panels

Rubber & polyurethane tension mats



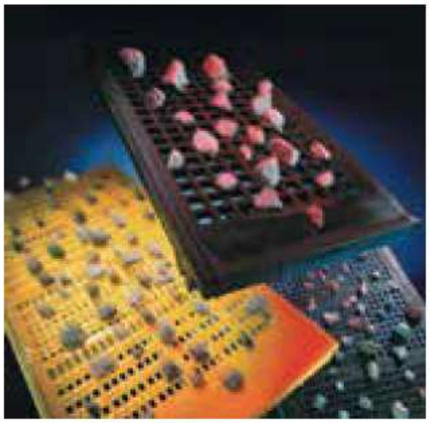
Rubber & polyurethane bolt down panels



Wear parts – Screening

Antiblinding rubber mats

Rubber / polyurethane modular systems

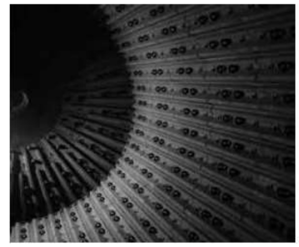


Wear parts – Grinding

Rubber linings

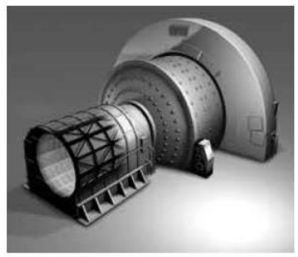
Poly-Met® linings

Metallic linings



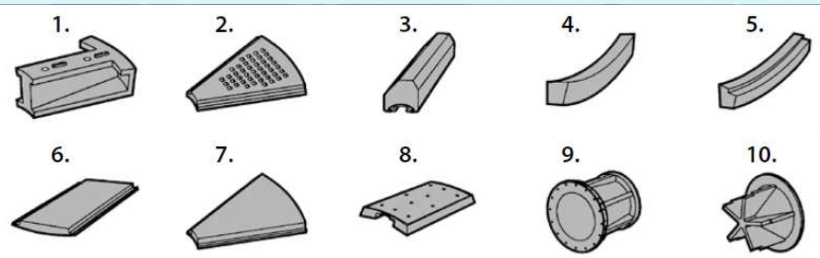
Orebed® linings

Trommel screens



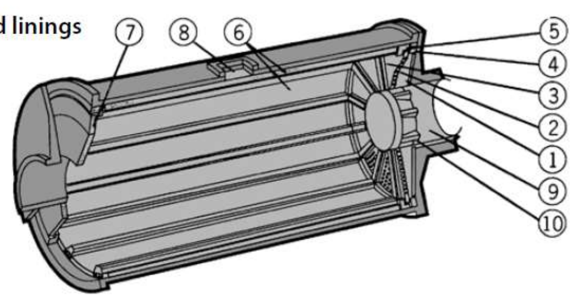
Discharge systems

Tumbling mill – lining components

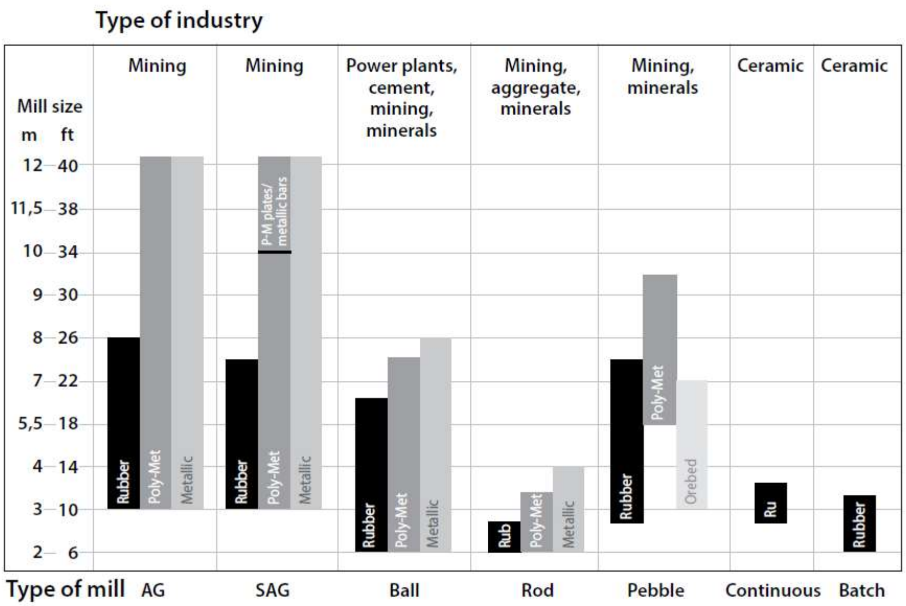


Lining life time – standard linings "ball park figures"

Type of mill	Months
AG	8 – 18
SAG	3 – 12
Rod	6 – 24
Ball	6 – 36
Pebble	12 – 48

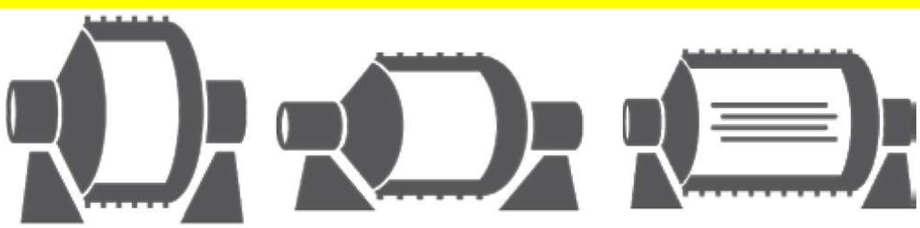


Linings for mills



Discharge systems, trunnion linings and trommel screens are suitable for all sizes.

Tumbling mill liners – material



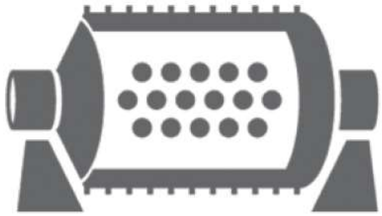
Dry: Metal (white iron) or Cr-MO
Wet: Metal (white iron, Cr-MO or Poly-Met)

Dry: Metal (Cr-Mo)
Wet: Metal (Cr-Mo or Poly-Met)

Dry: Metal (white iron) or Cr-MO
Wet: Metal (white iron) Rubber and Poly-Met, or Cr-MO
Head liners in rod mills are always Cr-Mo

Tumbling mill liners – material

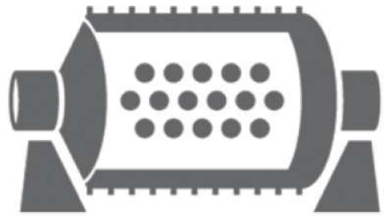
Ball and Pebble mills



Primary or secondary mills: Rubber or Poly-Met. Select type of insert based on level of impact in the mill.

Regrind: Rubber

SRR mills



Dry-rod: Metal

Dry-ball: Metal (or rubber if temperature not critical)

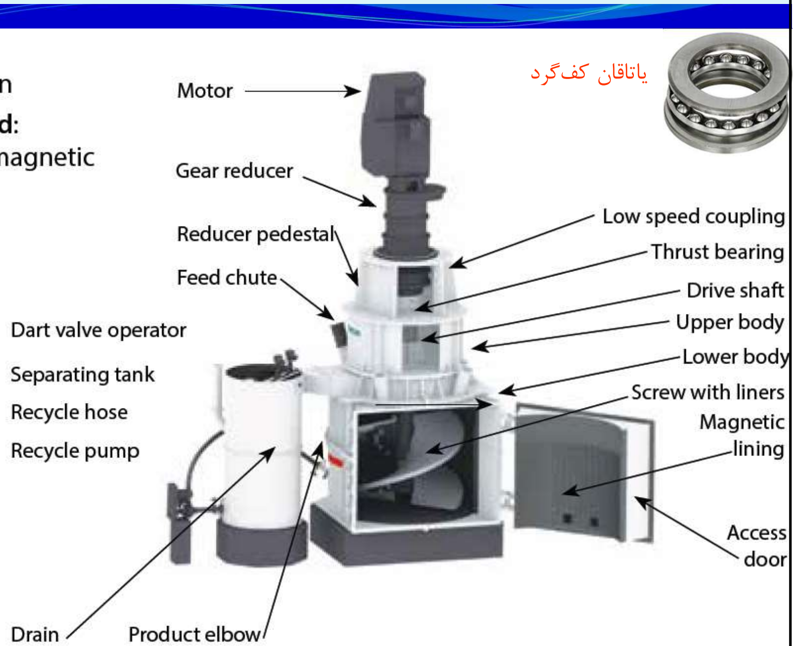
Wet-rod: Metal or rubber

Wet-ball: Rubber

VERTIMILL® – Liners

Screw lined:
with White iron

Chamber lined:
with Orebed magnetic liners.



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Something about ceramic liners

- Although ceramics have high resistance against wear, temperature and most chemicals, they have never really been accepted as day-to-day standards in Slurry Pumping.
- Being both brittle and expensive to manufacture.
- Development work on ceramics continue in an attempt to improve the possible acceptance.